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Bay of Fundy Scallop Analytical Stock Assessment and Data Review 1981-1994: Digby Grounds

by

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Abstract

The research vessel survey, port sampling and fishery data bases for the Bay of Fundy are reviewed from 1981-1994. Despite deficiencies in the data, VPA analyses using these data, appear to give good results except in years of high recruitment, the effects of which are discussed.

Landings in 1994 were 211 mt for the outside zone with fishing mortality ranging from 0.26 to 0.44 for recruited age-classes. However, it should be noted that even with the relatively light effort taking place on these beds in 1994, in contrast to earlier years, fishing mortality was still close to F_{max}. Inside zone landings were 129 mt in 1994, and estimates of fishing mortality range from 0.12 to 0.17. This level of fishing is consistent with fishing below $F_{0.1}$. Historically, the Digby stock has been heavily over-fished, with fishing mortalities as high as three times F_{max} occurring regularly, especially in the inside zone.

Abundance is at the lowest level recorded during the past decade (1983-1994), and biomass is also low. Abundance has declined approximately 24% from 1993 to 1994, however, biomass was only reduced by approximately 6% (VPA estimates). There have been no strong year-classes since the large recruitment pulses which entered the fishery in 1988 and 1989. Approximately 55% of the stock is over the age of 7, with over 20% of this aged 10+. The exploitation rate for the inside zone is currently low, at roughly 10%, with the outside zone at 30%. CPUE has fallen to an average of 2 kg/hm, which is very low, however prices remain very high, especially for the larger meats. The 1995 catch projections based on these values results in yields of 246 mt fishing at $F_{0.1}$ and 360 mt fishing at F_{max} for the inside zone, and 227 mt fishing at $F_{0.1}$ and 348 mt fishing at F_{max} for the outside zone.

Résumé

On examine les données provenant des relevés de recherche, de l'échantillonnage au port et de la pêche dans la baie de Fundy pour la période 1981-1994. Malgré leur lacunes, elles ont servi à établir des APV qui semblent donner de bons résultats, sauf dans les années de fort recrutement, dont on discute ici des effets.

En 1994, les débarquements étaient de 211 tonnes métriques pour la partie extérieure de la zone et la mortalité par pêche variait de 0,26 à 0,44 dans les classes d'âge recrutées. Il convient, toutefois, de noter que même avec un effort de pêche relativement faible dans ces gisements en 1994 par rapport aux années précédentes, la mortalité par pêche reste proche du niveau F_{max}. Dans l'intérieur de la zone, les débarquements étaient de 129 tonnes métriques en 1994 et les estimations de mortalité par pêche se situaient entre 0,12 et 0,17. Cet effort de pêche est inférieur au niveau $F_{0.1}$. Traditionnellement, le stock de Digby a été très surexploité; les mortalités par pêche équivalant à trois fois le niveau F_{max} étaient fréquentes, en particulier dans l'intérieur de la zone.

L'abondance est à son niveau le plus bas de la période 1983-1994. La biomasse est également faible. L'abondance a reculé d'environ 24 % de 1993 à 1994, mais la biomasse n'a diminué que d'environ 6 % (estimations de l'APV). Il n'y a pas eu de fortes classes d'âge depuis les grandes poussées de recrutement connues en 1988 et 1989. Environ 55 % du stock a plus de 7 ans, et 20 % de cette proportion en a plus de 10. Le taux d'exploitation pour l'intérieur de la zone est actuellement faible, de l'ordre de 10 %, tandis qu'il est de 30 % dans la partie extérieure de la zone. Les PUE sont tombées à une moyenne de 2k/hm, ce qui est très faible. Toutefois, les prix demeurent élevés, en particulier pour les grosses chairs. Les projections de prises fondées sur ces données pour 1995 indiquent des rendements de 246 tonnes métriques à $F_{0.1}$ et de 360 tonnes métriques à F_{max} dans la partie intérieure de la zone, et de 227 tonnes métriques à $F_{0.1}$ et de 348 tonnes métriques à F_{max} dans la partie extérieure de la zone.

Introduction

The Inshore Scallop Advisory Committee (ISAC) is in the process of reviewing a management plan for the Bay of Fundy scallop fishery. Accordingly, Science Branch has endeavoured to provide ISAC and managers with the information required to develop a plan which will have conservation value. In 1993, two documents were published in the Atlantic Fisheries Research Document series (Kenchington and Lundy, 1993 a and b) in direct response to requests from management. Under discussion was the replacement of some of the current size restricting regulations with a minimum meat weight. The minimum size of sea scallop landed in the inshore scallop fishery is determined by gear ring size, meat count and minimum shell height. Minimum shell height enforcement requires boarding vessels at sea, as the scallops are not landed in their shells, and the meats are processed at sea. A request for a minimum meat weight to correspond to a minimum shell height was made with the view of enabling a more efficient enforcement system. In this initial document, the estimated meat weight corresponded to the current shell height regulation (76 mm). However it was recognized that there was no scientific basis for the current size regulation. Consequently, in 1994, a yield-per-recruit analysis was published which recommended scientifically-based seasonal, minimum shell height, minimum meat weight, and meat count values (Roddick et al. 1994). The yield-per-recruit analysis also recommended levels of fishing effort. At $F_{0.1}$ both egg production per recruit, and the standing stock biomass were estimated to be about 50% higher than at the F_{max} level. With the yield-per-recruit analysis completed, it became obvious that the level of fishing effort must be estimated in order to place the fishery in perspective. In the meantime, radically different management options were being considered, and information on a biologically-based division of the scallop beds in the Bay of Fundy into fishing areas was requested. These fishing areas were to define contiguous scallop beds that have been persistent through time. Four such areas have been defined: Grand Manan and surrounds; below Digby Neck and above latitude 43°40'N; the upper reaches of the Bay of Fundy; and the Bay of Fundy proper encompassing the traditional fishing grounds off Digby, N.S. and the sporadic fishing grounds off Cape Spencer, N.B. This information is documented in the second research manuscript produced in 1993 (Kenchington and Lundy, 1993 b). With the delineation of these fishing areas, information was requested on their yield capacity, and on the recommended catch per area. Thus, with data required on fishing effort and on recommended catch, a population analysis (VPA) was requested for the Digby Stock. In this document, we review our data on the Digby stock and assess different methods for determining numbers at age in the stock. Weaknesses in our data set are discussed. A VPA with 1995 stock projections is presented for each of the inside and outside zones off Digby.

Data Sources

Research Vessel Survey Sampling Procedures

Research vessel surveys have been carried out on the Digby stock since 1978 under the direction of three research scientists: Drs. Glen Jamieson (1978-1980), Ginette Robert (1981-1989) and Ellen Kenchington (1990-1994). However, to the best of our knowledge, the data from the surveys prior to 1981 have been lost (G. Robert, pers. comm.). During this period there was one senior scallop technician, Mark Lundy. The surveys have consistently been conducted in June using commercial gear. However the sampling design for the research vessel biomass surveys has not been consistent. From 1981 to 1989 the survey stations were randomly assigned within catch strata (Fig. 1A). Three catch strata (high, medium and low) were defined according to the catch distribution reported by fishing log information over specific periods (Table 1). High stratum areas were defined as areas with greater than 3% of the total Class 1 catch (determined from logbooks with complete information), medium stratum with 1 to 2.9%, and the low stratum with less than 1%. In addition, an "exploratory" stratum was surveyed, defined as areas with less than 5 days of effort occurring during the period used to define the catch strata. The number of stations allocated to each effort stratum was arbitrarily determined proportional to the number of disparate fishing locations within each stratum (Table 2A). For example, in 1982, the station allocations for each stratum were 15, 20, 40 and 25 respectively. However, fishing log compliance fell dramatically in the late 1980's (see below) with only 14.6% of the fleet reporting in 1989 and 13.8% in 1990. Through this period, the validity of the catch stratification became increasingly uncertain, and in 1991, the sampling scheme was changed to one which randomly assigned stations by area.

From 1991 to the present, survey stations were randomly assigned according to one of three areas: Core Area, Below Core Area and Above Core Area (Robert et al. 1984), which were originally defined according to commercial catch distribution levels (Fig. 1B). In 1991 and 1992, the Area Strata were arbitrarily assigned 75, 10 and 15 stations respectively with the intent of weighting the number of stations in favour of the Core Area, which has historically been the most productive. In 1993 and 1994, the number of stations per stratum was changed to reflect the relative geographic area of each stratum. Accordingly 53, 16 and 31 stations were assigned to the Core Area, Below Core Area and Above Core Area strata respectively (Table 2B). Not all stations could be completed every survey, but in most years coverage was greater than 90%. Stations were randomly assigned within the Below Core Area and Above Core Area strata. Within the Core Area stratum, the number of stations was further stratified by fishing zone (Fig. 1B): general fishing zones referred to by a prominent shore location, i.e. Gulliver's Head, Digby Gut, Delaps Cove etc. These zones are defined by 4 mile wide bands running perpendicular to the shore and extending from the 1 mile band to approximately 16 miles. The exceptions to this are the Centreville area which only extends to 10 miles, and the Digby Gut area which extends to 16 miles but is of 6 mile width rather than 4. These rectangles reflect the catch reporting terminology used by the fishermen in their logs prior to the use of 'Loran'. The number of stations per fishing zone within the Core Area (Table 2B) were determined by the percentage of square miles of the Core Area represented by the fishing zone substratum. Station location within a fishing zone was then randomly selected. In 1990, 1991 and 1992, additional stations were added to accommodate a genetic sampling program (Kenchington 1994). These additional stations were randomly selected within 2 mile distance intervals per zone, in order to ensure two stations per interval. Where two or more stations randomly occurred within a distance interval from the survey allocation, no new stations were added. Where less than two sites occurred within an interval, additional sites were added to bring the total number to two. As sampling procedures were the same at these additional stations, the frequency distribution of the catch was also recorded. These stations were included in the total number of survey stations (Table 2B).

The traditional survey area off Digby, N.S. encompasses the resident scallop stock. The area from which the biomass is estimated has remained the same since 1985 (Fig. 1A, B) and can loosely be described as 1-16 miles off the designated shore references between Gulliver's Head and Hampton on the Nova Scotia coast. Off Centreville, the survey area only extends to 10 miles. Prior to 1985 little commercial effort was seen in the upper reaches of this area, specifically Young Cove, Parker's Cove and Hampton. Fishermen attribute the expansion of the bed to the effect of concentrated dragging. In 1981 the survey area was only from Centreville to Delap Cove but was extended to Parker's Cove for the 1983 and 1984 surveys.

Prior to 1989 all survey work was conducted on a chartered Digby commercial scallop vessel using 7 gang gear. Since 1989 the research vessel "J.L. Hart" has been used with 4 gang gear. The actual gear configuration has remained the same for all years except for the introduction of rubber washers in 1983. The 76 cm inside width drags are made of 7 rows of 4 mm steel wire rings 75 mm inside diameter, 9 across and 3 on the side fastened to an angle iron frame at the mouth and a piece of wood (2"x4") or plate steel at the tail end. This gear actively selects against small size scallops. Small scallops can avoid the drag path, or if caught, escape through the steel rings (Robert and Lundy 1989). To estimate the relative abundance of small scallops (< 80 mm shell height) some drags were lined with 38 mm polypropylene mesh. However the abundance of scallops with shell height under 40 mm is not reliably estimated and can only be used as an indication of recruitment. For analysis purposes the average number of scallops caught in unlined gear (> 80 mm) and the average number of scallops caught in lined gear (≤ 80 mm) were used and then prorated to conventional 7 gang gear to allow for annual comparisons. The number of drags (both unlined and lined) sampled varied prior to 1989 (Table 3). In particular the placement of the lined gear varied, which could result in differing catch rates of the small scallops. All tows were 8 minutes in length. To eliminate the effects of tide and vessel speed on the area covered by the gear, the distance towed was determined either from latitude/longitude of the start and end of tow bearings, or from continuous at-sea recordings of location via a computer linked to Loran navigation aids, and standardized to a tow length of 800 meters (dragged area of 4256 sq. m). Data recorded for each tow were: 1) direction of tow (magnetic or true compass bearings), 2) depth (m), 3) weight of catch (kg) (individually for each drag), 4) types of substrate, 5) bottom temperature (1990-1994 inclusive) and 6) shell heights in 5 mm intervals for all live and dead (empty paired shells) scallops fished recorded individually for each drag. Scallops from selected tows were collected for the calculation of meat weight-shell height regressions and ageing (see Biological Data below).

Port Sampling of Commercial Catch

Port sampling of the commercial catch has been carried out in Digby, N.S. since 1981. However, in 1981 and 1982, the location of the catch was not defined. Monthly sampling of the catch is very uneven (Table 4, 5) especially prior to 1992. Resource personnel difficulties and cost restraints generally restricted sampling during November to April, the traditional period of the inside zone fishery. During this period the data collected was strongly biased toward vessels operated by one company and may not reflect the catch of the whole fleet (Table 6). In May 1992 contracts were established with industry to allow sampling on a year round basis from selected vessels of various companies. This strategy appears to give better coverage of the fleet activities, both in terms of number of vessels sampled and the monthly distribution of samples (Table 4, 5, 6). In 1993 the percentage of samples from 2-4 vessels increased from 1992, mainly due to the majority of the fleet landing in Yarmouth as fewer vessels were fishing in the traditional Bay of Fundy area.

Representation of the catch by area is also inconsistent. Another set of areas, based on distance from shore, are used to subdivide the data. The inside zone in this breakdown refers to any samples collected from < 6 miles off N.S. between Centreville and Hampton (traditional 'inside' survey area) and should not be confused with the regulation inside zone < 6 miles off N.S. between Centreville and Parker's Cove. During the 1980's sampling occurred generally from catches of the outside 6 mile zone between May and September inclusive. Sampling of the inside zone during this time frame is either nonexistent or minimal at least.

When a vessel lands, two samples of approximately 500 grams each are removed from the catch, and date, vessel, location and depth fished are recorded. The catch muscle is then removed from the adductor muscle and all muscles are weighed and recorded for each of the two samples. This separation of the muscles is done because the catch muscle is usually removed from the adductor during processing. The weight of the catch muscle, however, has been calculated as 5-7% of the total weight and it would be possible to prorate these data to account for the weight of the catch muscle. However, fishermen do not remove the entire muscle when "shucking" the meat. A portion of the muscle is commonly left on each valve. The percent of the meat discarded has not been calculated for Digby shuckers, and is expected to vary with shell shape in the different parts of the Bay, and with catch abundance. Data analysis establishes a frequency distribution, in 2 g intervals, of the adductor meats in the catch by year, quarter and area fished (see also Biological Data below).

Biological Data

During the period 1982-1989, samples from both the commercial catch and the annual research vessel (RV) survey were collected to provide biological data on the stock. These data were used to study growth rates and to calculate height-weight regressions.

Ageing Data

The commercial ageing data is not a random sample of the population, but drawn from the size range of the scallops found in the commercial catch, with few small or large animals represented. Fishermen were asked to bring in a bushel of live scallops in the shell, collected randomly from a single tow. From these, the port sampler would select 30 animals representative of the full range of shell height found in the bushel sample.

Similarly, data collected during the survey is not representative of the frequency distribution of the population. The 30 scallops sampled per tow were also selected to include the full size range in the catch. Also, tows which did not have a broad range in shell height were not sampled, even if they had been pre-selected for this type of sampling.

The rationale behind this protocol was to establish a range of shell heights for regression purposes. Random samples of the catch would have most likely produced a cloud of data around the common age-class to which the regression fit would have been poor. Scallops were aged in the lab by the count of the annual rings on the shell (Bourne 1964). Ageing by this method is thought to be accurate to ± 1 year (Roddick et al. 1994).

From the combined commercial and survey ageing data set, the mean shell height and standard deviation for each age-class, by zone, were calculated. These data were used as the starting input parameters for the modal and VPA analyses detailed below.

Population growth curves were fit separately for the inside and outside zones off Digby using a computer program developed by Allen (1967) following Fabens' method. The program iteratively estimates k and L(inf) before estimating t(0). These growth curves were fit using data from all "rings" (multiple data points per individual) with a two-part weighting scheme to alleviate bias by a Rosa Lee effect (Roddick et al. 1994). The data were weighted by 1/N, where N equals the number of rings per individual. This weighting reduces the bias introduced by multiple data recorded from old, slow growing animals (Roddick et al. 1994). In order to be representative of the population, the data from 1982-1989 were combined and the total weight of each 5 mm size group in the aged sample was set proportional to the percentage contribution of that size class in the 1982-1989 survey length frequencies. This weight was then split evenly between all scallops in the aged size group (Roddick et al. 1994).

The parameters of the von Bertalanffy growth equations with the standard error in brackets are:

Inside Zone (N=780)	K=0.2389 (0.0001)	$T_{(0)}$=1.3954 (0.0005)	$L_{(INF)}$=139.789 (0.03282)
Outside Zone (N=9188)	K=0.2796 (0.0001)	$T_{(0)}$=1.4361 (0.0003)	$L_{(INF)}$=125.839 (0.01999)

Statistical comparisons of the two fitted growth functions, against a function fit to the combined data, were made by analysis of the residual sum of squares (ARSS) and examination of the goodness-of-fit (Chen et al. 1992). Fitting separate functions to the data according to fishing area, was a significant improvement over using a single function. Separate growth curves for each area were used in the analyses detailed below.

Meat Weight-Age Regressions

The relationship between age (x) and meat weight (y), in the scallops from the above data set, was examined using both linear and non-linear equations by fishing area and quarter. No data were available to determine this relationship in the inside zone during the 3rd quarter (July-September), however, only the regressions calculated with 2nd quarter data were used in the VPA (see below). Linear regressions of the untransformed data provided the best fit:

Inside zone	April-June	y=4.088-10.159x	R^2=0.80	n=150
Outside zone	April-June	y=1.667-0.450x	R^2=0.51	n=921

Both of these regressions are significant at P<0.01.

Shell Height-Meat Weight Regressions

The samples used for calculating the relationship between shell height and meat weight include those collected for ageing purposes (see above). In addition, shell height and meat weight samples were collected seasonally, as part of a study on seasonal changes in somatic and reproductive tissue weights (Kenchington et al. 1994). Scallop samples were collected aboard the Brannetelle, a commercial 54' Digby scallop dragger owned and operated by Vance Hazelton, Hazelton Fisheries Ltd., Digby. Four random locations were determined for each of the two fishing zones prior to sampling. Seventy-two scallops were randomly collected from each tow. The wet weight of the adductor muscle, gonad and soft parts (mantle and other organs) were recorded to 0.01 g. Sampling dates are given in Table 1 of Kenchington et al. (1994). Data from these three sources was used to calculate quarterly regressions by area of the ln (shell height) on ln (meat weight):

Inside Zone	January-March	y=3.971+0.249x	R^2=0.90	n=921
< 6 miles	April-June	y=3.938+0.261x	R^2=0.87	n=1999
	July-September	y=3.915+0.282x	R^2=0.85	n=696
	October-December	y=3.892+0.265x	R^2=0.89	n=1069
Outside Zone	January-March	y=4.009+0.240x	R^2=0.90	n=695
6-15.9 miles	April-June	y=4.057+0.232x	R^2=0.84	n=2889
	July-September	y=4.016+0.251x	R^2=0.81	n=2191
	October-December	y=3.897+0.268x	R^2=0.87	n=565

All regressions were highly significant.

Shell Height Frequency Distributions

During the June research vessel surveys, all scallops are measured into 5 mm shell height increments; sub-samples are used only when the catch is extremely large and the sub-sample numbers are then scaled up by weight. All catches are prorated to a standard 800 m tow length. To estimate total numbers for this study, simple areal expansion of area towed to total survey area was used (see below). This is done individually for each 5 mm shell height interval.

Fishery Data

All Full Bay of Fundy license holders are required to provide log book information which provide data on catch, location and effort. Currently, 99 vessels are required to report. Although a limited entry policy has been in effect since 1973 some additional licenses have been approved since. The number of licenses have not changed since 1988 (Kenchington and Lundy 1992).

Log compliance fell dramatically in the late 1980's (Table 7) but through personal contact and increased collaboration with industry, it has been steadily increasing. While a single log record from a licensed vessel would qualify as compliance, no fewer than 5 logs have been received from any one vessel since 1990, and most of those complying, fully report.

Due to the variability of log compliance and the somewhat meaningless methods by which Statistics Branch catches are reported, it is difficult to assign catch levels to specific fishing areas. Statistics Branch catches are reported in two ways: 1) NAFO subdivision, and 2) district landed. For the Bay of Fundy scallop fishery, there are three NAFO subdivisions, 4Xq, 4Xr and 4Xs. The line between 4Xr and 4Xs is drawn 9 miles from the Nova Scotia shoreline at Digby, and divides the scallop stock, making it impossible to assign catches to particular areas. Statistics Branch catches by district are derived from sales slip data, and only give the port of landing. Logbook catches are also broken down into NAFO subdivisions but are incomplete due to the level of compliance (Table 7). To further complicate this issue Statistics Branch catches were broken down by vessel tonnage, ≤ 25 G.T. and > 25.5 G.T. Although the Bay of Fundy fleet is in the > 25.5 G.T. range, some Mid-Bay licensed vessels are also of this size class. Statistics Branch catches were not broken down by license type until 1988.

Catch trends were estimated using the fishing logbook data available. Catches were broken down by area (distance areas given in Table 4, 5) using the log data where location fished was known. Some logs provided full information (Class 1), others had only location and catch (Class 2) and still others had only general fishing area and catch with or without effort (Classes 3 and 5). The percent catch per area off Digby, of the total Class 1 and Class 2 logged catch was calculated and the estimated catch per area was derived from the total sales slip catch reported by Statistics Branch. For example, if the percent of total Class 1 and 2 logbook catch reported for the < 6 mile area was 60%, then the estimated catch for that area would be calculated as 60% of the Statistics Branch sales slip catch. For other areas, the total Class 1, 2, 3 and 5 log data was used to prorate. Prior to 1988 the total Statistics Branch sales slip catch used was that caught by vessels > 25.5 G.T. From 1988 to the present, the Full Bay license holders sales slip landings were used. This data is more reliable as it excludes other licensed vessels from the catch, as these are the only licenses eligible to fish in the Digby area.

Fishermen report their landings, and sell their catch in terms of pounds of meat. Statistics Branch converts this to round weight (whole animal) using a conversion factor of 8.33. To convert Statistics Branch landings to metric tonnes of meat, the data are re-converted to pounds of meats and then converted to metric weight in tonnes. Estimated landings (Table 8) were derived for : 1) 1-5.9 miles off the Digby coast, 2) 6-15.9 miles off the Digby coast, 3) outside 16 mile zone within the Bay of Fundy, 4) Brier Island area, 5) German Bank/Lurcher area, 6) Browns Bank, and 7) Georges Bank.

The estimated catch (Table 8) was broken down by year, quarter and area fished (Table 9). Catch per unit effort (CPUE) was calculated from the Class 1 log data. Total effort was calculated by increasing Class 1 effort proportional to the difference between the Class 1 and total catch (Table 10).

Preliminary Data Analyses

Comparison of Methods: I. Determination of Numbers at Height

Simple Aerial Expansion

In order to calculate the number of scallops at height in a given area, simple aerial expansion of the survey data was applied. The number of scallops per standard tow (dragged area of 4256 sq.m) were determined for each 5 mm height interval from 0-200 mm and summed across all tows in a given year (Table 11A, B). These numbers were then multiplied by the total area divided by the area covered by the tows. The inability of our survey data to accurately quantify small scallops is emphasized in Table 11.

One of the main discrepancies in this data appears in the 1985 survey. That year, the survey did not detect any scallops less than 25 mm in the inside zone, or less than 20 mm in the outside zone. However in 1986, the survey detected very large numbers of scallops in the 25-45 mm shell height groups in both areas, in fact one of the largest recruitment pulses seen in the fishery. Re-examination of the 1985 cruise log confirmed this anomaly. Yet in other years, for example 1983, relatively large numbers of small scallops under 25 mm were sampled. Examination of the original logbook records indicates that when the inside fishing zone opened in October, 1985, small scallops were present. In general, very few vessels made comments on their logbooks. However, the Dawn til Dusk, fishing 2-3 miles off Gulliver's Head the first two weeks of October, reported "small scallops showing up inshore as big as a dime and smaller, looks like there might be a lot in some places." There were no reports of small scallops prior to September. By 1986, similar comments were made throughout the year as the scallops started to appear more often in the catch. Scallops the size of a dime in October 1985 would have been very small (less than 5 mm) during the June survey. It may be that these scallops were part of a spring spawn. The growth characteristics of this cohort is distinctive, showing much higher growth than other year-classes (see VPA below).

Delaunay Triangulation

Simple aerial expansion of the survey data does not allow for spatial heterogeneity in the scallop bed. The spatial distributions of scallops on the Digby beds, determined from the biomass surveys, have been presented in CAFSAC Advisory documents using a contouring approach since 1990 (Robert et al. 1990). The spatial distribution of the scallops is contoured using the ACON software package (Black 1988) with data derived from Delaunay triangles and inverse distance weighted interpolation (Watson and Phillip 1985) as detailed in Robert et al. (1990). In brief, scallop density is integrated over a triangular area, the vertices of which are defined by nearest neighbour tow locations. The composite of triangles forms a polygon, the area of which is defined by the outlying tow locations which form the edge points (Table 12).

The Core Area (Fig. 1) has a greater density of survey stations than other areas of the scallop bed. With a greater density of stations within a defined area, we might expect that the polygon within the Core Area, defined by Delaunay triangulation, would not vary much in size from year to year (Table 12). However, we found that the area changed by as much as 37%, and thus we have not been able to integrate this method into our analyses. Calculation of numbers at height using this method would give a more precise estimate than the simple aerial expansion method. However, the software does not yet allow extrapolation to a common area (necessary for population analyses), which would require the calculation of density estimates at the pre-defined area periphery.

Summary

Simple aerial expansion was used throughout to estimate the number of scallops on the fishing grounds. The Delaunay triangulation method would give an improved estimate, however the program needs to be adjusted to calculate peripheral data points within a set area before it can reliably be used quantitatively.

Comparison of Methods: II. Determination of Numbers at Age

In order to compare the internal consistency of the different methods by which height frequencies are broken down into age frequencies, tables of calculated Zs ($Z = -\ln(N_1/N_0)$)were constructed for each method. These Zs are not adjusted for selectivity or other effects and thus are not good estimates of total mortality. They are presented as a simple means of visualizing the internal consistency of the data, i.e. we expect negative values for partially recruited age-classes, and positive values for fully recruited ones. To distinguish our use of Z from the Z used to estimate total mortality, we will use an italic symbol.

Delaunay Triangulation

The number of scallops-at-height determined by Delaunay triangulation are readily converted to the number of scallops-at-age (Table 12). Here we have used three depth-defined von Bertalanffy growth curves, established using data collected from 1982-1985 inclusive (Robert et al. 1985, Robert et al. 1990) to convert the data using straight cohort slicing (see below). This is the form in which the survey data are tabulated (e.g. Kenchington and Lundy 1992). However, as the initial estimates of the number of scallops-at-height are not useful for inter-annual comparison, this method is not considered further here.

Cohort Slicing

Cohort slicing is a method by which the catch-at-height matrix is converted into a catch-at-age matrix using only the mean size-at-age to partition the height distributions for each year. The slicing points fall half-way between the mean values of successive age group means. This method does not take into account variations in year-class strength, which will change the proportions assigned to adjacent age-classes when their height distributions overlap. Cohort slicing is the simplest conversion method and should give good results for the younger aged scallops, where the rapid growth results in little overlap in the size distribution of adjacent ages, but is expected to do poorly in the older age groups as the overlap increases. Cohort slicing was applied to the yearly height distributions determined by simple aerial expansion (Table 13) for the area less than 6 miles, the area between 6 and 15.9 miles and for the total area. The *Zs* estimated for the inside and outside zones are given in Table 14 (A, B).

The numbers at age and *Z* Tables show that there is a considerable "smearing" of large year-classes, especially in the two large year-classes going through the fishery in the late eighties. These year-classes show strongly as two year-old scallops in 1986 and 87 but by 1989 the high numbers are spread over six year-classes as overlap in the size distribution increases and the tails of the size distribution of these strong year-classes are assigned to adjacent ages. Positive *Zs* appear as early as 2/3 and negatives as late as 6/7. The negative *Zs* dominate the smaller year-classes (1-5). The effects of smearing strong year-classes are seen and there is some interspersion of positive and negative values. Overall the pattern is much as would be expected from the growth function, and slicing appears to be an acceptable method for producing the catch-at-age matrix.

Age-Height Key

In order to construct an age-at-height key (age-length in fish), aged sub-samples of the catch are required. Our samples of the commercial catch were not collected for this purpose, but were directed at the height frequencies encountered in the commercial fishery. Small and large scallops are under-represented in this data set. Examination of the age-height distributions for the inside zone showed that coverage was sporadic throughout the size ranges, and thus an age-height key could not be constructed. For the outside zone it was found that the size range for ages 5-10 was adequately sampled to allow the construction of partial (age 5-10) age-height keys for each year. An example of one such key constructed with 1988 data is given in Table 15. The numbers of scallops at age, for ages 5 -10, for the outside zone (6-15.9 miles), from 1983-1988, are shown in Table 16.

The age-height key appears to smear age-classes to a similar or greater degree as the slicing method. This concurs with our evaluation of the ageing data, which we believe to be accurate to ± 1 year. In this instance, this method does not appear to be an improvement over the slicing method. The Zs calculated from this breakdown are shown in the bottom half of the Table. Unlike the Zs produced from the sliced data, they show large negative values as far down as the oldest age groups considered (9/10). This is largely restricted to the 1984-85 comparison. A considerable variation in values for a given age group between years occurs, but this is in common with the slicing method. In conclusion, this method cannot be applied to the Digby stock assessment due to our data coverage. However, where comparisons were possible, this method does not appear to be a marked improvement over cohort slicing.

Modal Analysis

The height frequency distributions (Table 11A, B) were analyzed as mixtures of age groups using the Mix 3.1 software package (MacDonald and Green 1988, MacDonald 1994). Each age group distribution, termed a component, was defined as having a normal distribution. The mean shell height and standard error for each age group were determined from aged samples collected in each area from 1982-1989. The survey did not adequately sample animals less than three years of age, and thus the first component in the mixture generally equates to 3 year-old animals. Seven age components were used in the analyses, with the last component lumping animals age 10 and over. This component was not fitted differently from the other components (MacDonald and Green 1988). The overlapping component distributions were fit to the height frequency data using a maximum-likelihood estimation for grouped data. The proportion of scallops in each mode was applied to the survey data (Table 11A, B) to produce numbers of scallops per mode by year and fishing zone (Table 17). The shell height frequency distributions are compared to the modal analyses numbers in Fig. 2A, B.

The modes produced by the modal analysis do not align well from year to year. Large year-classes appear from nowhere and others disappear very quickly. The Z values (Table 17) show a similar pattern to those produced by cohort slicing, however, the dominance of negative Zs in the prerecruit classes extends heavily into the recruited classes.

Summary

In converting the number of scallops-at-height, to the number of scallops-at-age, simple cohort slicing was used in the following analyses. As indicated above, this method should give an improved estimate of the numbers in the fast growing, younger age groups. As the growth curve flattens out at ages 8 and above (see Roddick et al. 1994), this method will poorly estimate the numbers, especially if year-classes are uneven in strength. Our experience with the modal analysis approach was entirely negative, largely due the amount of subjectivity in fitting the parameters. The age-height key could only be calculated for the outside zone. Our ageing data set is compromised by the lack of commercial ageing data during the winter months when the inside fishing zone is open. The only samples we have for the inside zone are from the survey, and these are poor, with discontinuous height frequencies. With a properly designed ageing program, this method has the potential to improve our estimates of numbers at age. However, ageing programs are expensive, and with the topology of the growth functions of scallops, the improvement may not be significant.

Virtual Population Analyses

A virtual population analysis (VPA; c.f. Mohn 1994a, b) was used to produce matrices of population numbers, biomass and fishing mortality-at-age over time (c.f. Mohn and Cook 1993). These matrices were produced for each of the outside and inside fishing zones for the years 1983-1994. Height frequency distributions were converted to age frequency distributions through the use of mean height-at-age data (cohort slicing) rather than by use of an age-height key (Mohn 1994a, b). A non-linear least squares (NLLS) algorithm was used to tune the VPA population estimates against the survey estimates. Further iterations are run to refine the estimates of year-class strength and the minimum residual sum of squares from six separate runs determined the optimum solution (Mohn 1994a, b).

Methods

The survey data is recorded in shell height frequencies and data from the commercial fishery is recorded as a meat weight frequency. The catch-at-weight was converted to a catch-at-height using the quarterly regression models by area (see above). As the meat weight is recorded to 0.01 g accuracy, while the survey lengths are only recorded to 5 mm increments, the conversion was from the former to the later. Since the annual growth rate is so high and the VPA input is an annual catch-at-height matrix which is converted to a catch-at-age matrix, it is necessary to either perform the VPA on quarterly increments, or to standardize the catch-at-height data to a common quarter. In the following analyses, the later route was chosen and catch-at-height data were standardized to height-at-the-second-quarter (April-June), as the research vessel survey is done in June. The standardization of shell heights was done with regressions of mean height-at-age for the second quarter versus quarters 1, 3 and 4, for each zone:

Inside zone (< 6 miles)		
2nd quarter vs 1st quarter	$y=30.751 \times 10^{.0051163x}$	$R^2=0.97$
2nd quarter vs 3rd quarter	$y=36.362 \times 10^{.0042616x}$	$R^2=0.99$
2nd quarter vs 4th quarter	$y=35.845 \times 10^{.0042797x}$	$R^2=0.97$
Outside zone (6-15.9 miles)		
2nd quarter vs 1st quarter	$y=33.302 \times 10^{.0049595x}$	$R^2=0.90$
2nd quarter vs 3rd quarter	$y=36.200 \times 10^{.0044133x}$	$R^2=0.98$
2nd quarter vs 4th quarter	$y=42.541 \times 10^{.0034209x}$	$R^2=0.97$

Other input parameters to the VPA are selectivity (partial recruitment), mean and standard deviations of size-at-age, natural mortality (M), fishing mortality in the final year (F_{last}), and fishing mortality for the oldest age-class (F_{old}) or terminal F.

Outside Zone

The fishing mortality parameters are tuned iteratively within the VPA (Mohn and Cook 1993). The fishing mortality for the oldest age-class (F_{old}) was set to 0.3, and F_{last} was set at 0.1, to begin the iterations. Analyses using F_{old}=0.1 and F_{last}=0.3 were performed to provide alternate starting points to evaluate the tuning precision. Results using the first set of parameters are discussed here.

Since the initial selectivity was that of the gear (i.e. probability of being retained by the gear) (Worms and Lanteigne 1986), and not true fishing selectivity (i.e. probability of being captured), the selectivity calculated from the VPA fishing mortality estimates was re-entered into the VPA to tune this parameter. This was done by averaging F-at-age for 1991-1993, after first normalizing to the highest value within each year to turn them into selectivity vectors, and also to remove the effects of inter-annual variations in F. The resulting average vector was then normalized to it's highest value to form a selectivity vector.

The mean size-at-age was calculated from aged sample data (see Ageing Data above), and the standard deviations around these means were estimated for three groups of ages, 1-4, 5-10 and 11+.

Natural mortality (M) was initially set at 0.1 (Merrill and Posgay 1964). With M=0.1 over all ages and years, the VPA could not account for the 1989 die-off (Kenchington and Lundy 1992) of the large year-class, and consequently under-estimated the size of the year-class prior to 1989 (the die-off year). Subsequent analyses were run using a matrix of mortality based on the percentage of "clappers" (dead, empty shells) found in the surveys. The percentage of clappers (Cl) in the catch was converted to a natural mortality estimate (M) by the formula: $Cl=1-e^{-M}$. Assessment of the research survey shell height frequency distribution for the outside zone (Table 11B, Fig. 3) indicated that this area only received a single high recruitment year, with the scallops contributing to it having been born in 1984. Consequently, in the final analysis only mortality in this year-class was adjusted for. Year-classes on either side of the recruitment pulse were included to account for spill-over effects of the ageing conversion. Natural mortality for 4, 5 and 6 year-old scallops in 1989, and 5, 6, and 7 year-old scallops in 1990, was set at 0.9 (determined from size-specific clapper percents of approximately 60%).

The VPA tunes survey catchability (q) and year-class strength using a subset of ages (Mohn 1994a, b). Analyses were performed using three age subsets. The fishery generally catches scallops aged 5+, where there are no distinctive size modes in either the survey or catch data (Figs. 3, 4). Distinctive size modes are seen in the survey data for ages 2-4. It is therefore difficult to find a common set of ages which will optimize the parameters from the different tuning exercises. At present we have not been able to modify the program to accept different ages for the tuning of different indices. Tuning on ages 3-6 produced a VPA biomass which is much lower than that of the survey during the 1986-1990 period. Tuning on ages 5-7 produced the opposite effect, possibly due to an inability to account for the large year-class moving through the fishery. In our final analysis we present data tuned on ages 4-7.

Regressions of the sliced research survey biomass against the VPA model biomass for both the whole population and just with the ages used for tuning (4-7) were performed. Regressions of CPUE against the biomass of animals over the age of 3 calculated from the VPA were also performed. A retrospective analysis of the VPA results was performed by sequentially removing data over the last eight years (1994-1988).

Inside Zone

Most of the input parameters for the VPA analysis of the inside fishing zone were the same as those of the outside zone, with the exception of the growth model and natural mortality estimates. The growth model for the inside zone, as described above, did not fit the length frequency distribution from the survey data. The two large year-classes which appear in the surveys from 1986-1988, appear to have had extremely fast growth rates compared to the historic pattern. For this reason mean size-at-age for ages 1-4 was adjusted to fit the peaks of the survey data (Fig. 11). Because of the faster growth rate in this area, scallops enter the fishery at age 3 (Fig. 12). The fishing mortality for the oldest age-class (F_{old}) was set to 0.3, and F_{last} was set at 0.1, to begin the iterations.

The clapper ratio was higher in the inside zone with values exceeding 75% for some size classes. Natural mortality for 4, 5 and 6 year-old scallops in 1989, and 5, 6, and 7 year-old scallops in 1990, was set at 1.2 (determined from size-specific clapper percents of approximately 70%).

Results

Outside Zone

The resulting selectivity-at-age vector for 1994 was: 0.0000, 0.0000, 0.0004, 0.1189, 0.5864, 0.9568, 0.9832, 0.9095, 0.7355, 0.3014, 0.2053, and 1. The estimated catchability coefficient (q) for ages 4, 5, 6 and 7 were: 0.000137583, 0.00026796, 0.000405713, and 0.000538385, respectively. The parameter estimates for the estimated F-at-age in the terminal year (ages 6 and 7), from explicitly tuning the fully selected F in the terminal year, along with their standard errors and coefficient of variation were:

	Est.	Parameter	S.E.	C.V.
Age 6	1	0.311398	0.118612	0.380902
Age 7	2	0.320665	0.127722	0.398304

Sliced catch, survey and VPA population numbers and biomass, fishing mortality-at-age, and the residuals calculated for the tuning ages are shown in Table 18. The tuning for year-class strengths in the outside zone VPA did not result in an improvement over slicing, as the best residuals were obtained with the initial sliced data. Fishing mortality was high in 1986 on the 8 year-old scallops, and in 1990 on scallops 6 years old. The later suggests directed fishing on the large year-class (since it was not uniformly distributed over the grounds), and it can be seen that this year-class has supported the fishery in this area through to the present. Setting the fishing mortality for the oldest age-class (F_{old}) to 0.3, and F_{last} at 0.1, or using F_{old}=0.1 and F_{last}=0.3 as alternate starting points, made little difference in the results.

Figure 5 illustrates the correspondence between the VPA numbers and those from the q-corrected survey results. The main divergence between the two estimates appears in 1989, where the VPA estimates are much greater than those found in the survey. Since we know from the survey, that the large 1984 year-class was present in 1988 and that the die-off did not occur until 1989, we believe that the survey underestimates the population for this year. An examination of the distribution of 1989 survey stations in relation to the distribution of the large 1984 year-class (Fig. 6), shows that it was not adequately sampled. At the time, survey stations were assigned on a catch-stratified basis, and since this year-class had not yet recruited to the fishery, there was not much commercial activity in this area. In 1988, the VPA numbers are less than those of the survey. An examination of the VPA population and survey numbers at age (Table 18) shows that in both there is a misallocation of the large year-class, age 4 in 1988, into the age 3 numbers for that year. This has occurred to a much greater degree in the VPA, causing the model to underestimate the numbers at age 4-7 (Fig. 5). A regression of the sliced research survey versus VPA biomass, calculated over all ages, is shown in figure 7. R^2 was highly significant ($P< 0.05$). The slope of the regression is largely determined by the 1988 and 1989 data points. The 1983 data point has the largest residual from this regression line. This data point is the first in the series, and survey data at this time did not cover the area considered in the VPA. In 1983 survey stations were concentrated in the Core Area off Digby, giving an overestimate of abundance with aerial expansion of the data. A large residual is seen in the 1988 data point, however, with the uncertainties associated with the 1989 survey estimate, we believe that "true" regression line would be closer to the 1988 point. When just the biomass from the scallops in the tuning ages (4-7) is used, the 1988 point remains well above the regression line, which is significant at P=0.01 (Fig. 8). The 1989 point is below the regression line. The line is largely determined by these two points, neither of which we believe to be accurate. If our reasoning is correct, the 1989 point should be higher and the 1988 point should be further to the right.

The regression of VPA biomass of animals aged 3 or greater against CPUE (Fig. 9A) is highly significant ($P<0.01$). The close agreement between VPA biomass and CPUE lends support to the accuracy the VPA estimates. The regression of sliced research survey biomass against CPUE (Fig. 9B) is also highly significant, however there is a lower R^2 value.

Retrospective analysis (Fig. 10) of the data shows that biomass estimates are stable, with the exception of years 1988 and 1989, for reasons discussed above. The analysis shows that error in the current year appears to result in an underestimate of biomass, which would result in a conservative stock estimate. Fishing mortality estimates for the current year are also relatively stable, except for the years 1990 and 1991. This may be due to the large changes in F-at-age associated with targeting. In 1990 and 1991 our estimates of F would have been too high. This again would result in conservative advice.

Inside Zone

The selectivity-at-age vector for 1994 was calculated as 0.0000, 0.0000, 0.3699, 0.6969, 0.5729, 0.9195, 0.8537, 1.0, 0.7090, 0.4185, 0.2382, and 0.9140. The estimated catchability coefficient (q) for ages 4, 5, 6 and 7 were 0.000380100, 0.000558364, 0.00078197, and 0.000937671 respectively.

From the sliced run, which gave the best residual sum of squares, the parameter estimates for the estimated F-at-age in the terminal year (ages 6 and 7), from explicitly tuning the fully selected F in the terminal year, along with their standard errors and coefficient of variation were:

	Est.	Parameter	S.E.	C.V.
Age 6	1	0.172957	0.0693037	0.400699
Age 7	2	0.134245	0.0558423	0.415974

Sliced catch, survey and VPA population numbers, fishing mortality-at-age, and the residuals calculated for the tuning ages are shown in Table 19. Tuning for year-class strength resulted in an improvement in the residuals over the initial sliced data. The residual produced by slicing was 18.6 while the second tuning iteration reduced the residual to 14.6. Fishing mortality was high in 1989 on the 3 year-old scallops, and in 1991 on scallops 7 years old. Fishing mortality in 1989 was as high as 1.77, approximately four times F_{max} (see below). This high level of effort was in response to the die-off. The partial recruitment pattern changes according to the targeted year-class. The fishery is dependent on the strong 1984 and 1985 year-classes.

Figure 13 illustrates the correspondence between the VPA numbers and those from the q-corrected survey results. The iteration adjusting for year-class strength has reduced the difference between the VPA and q-corrected survey numbers in 1988. There is a very good correspondence between the VPA numbers and those of the q-corrected survey numbers. Survey coverage of the inside zone has been better than that of the outside zone, and we do not see such large discrepancies between the data sets. The large year-class is still evident in the survey results in 1989, prior to the die-off (Fig. 13), in contrast to the outside zone (Fig. 5). The main divergence between the two estimates appears in 1988, where the VPA estimates are lower than those found in the survey. An examination of the VPA population and survey and catch numbers-at-age (Table 19) shows that the large year-classes have been assigned different ages in the survey and catch matrices. This may be due to the fishermen selectively taking the larger animals from the incoming year-class, possibly by fishing in faster growing areas (we do not believe that selection was taking place before shucking, on the boat, in order to meet the meat count). The catch-at-size matrix for this area and period is based on data from a small number of samples. A regression of the tuned research survey versus VPA biomass, calculated over all ages, is shown in figure 14. R^2 was highly significant ($P< 0.01$). The slope of the regression is largely determined by the 1988 and 1989 data points. The largest residual is seen in the 1987 data point. When just the biomass from the scallops in the tuning ages (4-7) is used, the fit to the regression line is further improved (Fig. 15). The 1987 point has moved closer to the line in this model, indicating that the difference in the position of the data point for 1987 is due to a difference in the allocation of scallops in the size corresponding to age 3 in the survey data.

The regression of VPA biomass of animals aged 3 or greater against CPUE (Fig. 16A) is highly significant ($P<0.01$). The close agreement between VPA biomass and CPUE lends support to the accuracy of the VPA estimates. The 1987 point is high above the regression line and has the largest residual from the line. In 1987 the delayed opening of the inside zone, which was an effort to protect the incoming large 1984 and 1985 year-classes, caused CPUE to be overestimated as the best grounds were targeted in the short period it was open. The regression of tuned survey biomass against CPUE (Fig. 16B) is also highly significant ($P<0.1$), however it is not as good a fit as that using VPA biomass.

Retrospective analysis (Fig. 17) of the data shows that biomass estimates are relatively stable, with the main exception being 1989. In contrast to the outside zone, the current year biomass estimate is overestimated in some years (Fig. 17). Advice generated from the stock projection would thus have a good probability of being overly optimistic. Also in contrast to the outside zone, fishing mortality estimates for the current year are sometimes underestimated. The greatest errors are seen during the period that the large year-classes recruited to the fishery. An improvement in the growth model may improve this situation.

Discussion

The best fit to the model resulted in a 1994 biomass that was higher than that predicted by the VPA biomass versus CPUE regressions for both the inside and outside zones (Figures 9 and 16). When compared to the survey biomass (Figures 7, 8, 14 and 15) the VPA biomass is higher than predicted for the outside zone but lower for the inside zone. With the 1988 and 1989 points controlling the slope in all these regression lines, forcing the 1994 point onto the line would require an F close to 0.9 for the outside zone. This level of F is twice that seen earlier in the F matrix and is deemed to be unlikely in the present fishing situation. For the inside zone an F of 0.16 would put the 1994 point on the 3^+ Biomass versus CPUE regression line. This is very close to the 0.17 predicted by the model. The R^2 value, however, continues to improve up to an F of 0.41 before falling off. This improvement is slight, going from 0.7938 at an F of 0.17 to 0.7987 at $F = 0.41$, because of the dominance of the 1988 and 1989 points in determining the regression line.

The survey estimates have improved in recent years with the changes to the station allocation design, while the makeup of the fleet fishing these traditional grounds has changed dramatically. Most of the fleet is fishing the Brier Island beds with only a few vessels remaining on the Digby Beds. This would suggest that recent CPUE values may not be as good a tuning criteria as the survey estimates. In figure 9 when the VPA biomass and the survey biomass estimates are plotted against CPUE the VPA estimate for 1994 is above the line while the survey estimate is below the line.

Our VPA models were constructed with poor data bases. Survey area and distribution of stations were not constant over time. In particular, the 1988 and 1989 surveys did not accurately estimate abundance in the outside zone. In retrospect, this appears to have been caused by a poor distribution of tows in relation to stock density, brought about by the method of allocating stations according to historic catches. Our port sampling coverage is also poor, particularly for the inside zone prior to 1991. Inadequacies in the early port sampling data include samples from a restricted number of vessels combined with periods of no information. Finally, converting the catch data from meat weights to shell heights for input to the VPA, involves two conversions: a weight to height conversion and a conversion to height at the second quarter. Despite these deficiencies, the analyses appear to give good results within the constraints discussed above. Changes made in 1991 to the survey design and port sampling contracts will further improve the model. If management of the Bay of Fundy scallop fishery moves toward the use of a TAC, a VPA should prove to be a useful assessment tool, provided caution is used during periods of recruiting strong year-classes. Recent improvements in our survey and port sampling coverage should result in an improved basis for the analyses.

Given that there are concerns about the quality of the data being used for the analyses, the VPA appears to have done remarkably well in providing estimates that are explainable and in agreement with other independent estimates. It provides estimates of current fishing mortality rates and population numbers and biomass that can be used in making decisions in how to manage this fishery.

The analyses themselves were performed using a variety of input parameters which we have not detailed further here. In general, we are restricted to tuning off the older ages because of the incongruence between the survey and catch size matrices. The algorithms would not handle the inclusion of age 2 scallops in the tuning, although 3 year-old scallops could be included. As the 2 year-old scallops are such a distinct mode in the survey data, it would be an advantage to use this group in tuning the year-class strengths. However, the dramatic disappearance of the strong year-class, and the absence of 2 year-old scallops in the catch, may be factors which with the model is unable to cope. It may be possible to alter the model to allow for factors such as these, which are specific to this stock.

The lower fishing mortality observed in the inside zone in 1994 has not been generally true. In 1994, when the inside closed area opened, the catch rates were lower than the Cape Spencer bed and most of the fleet quickly left the inside area. This is in contrast to earlier years when most of the fleet concentrated in the inside area in the fall and winter, resulting in a high level of effort. It would appear that fishing mortality in the inside zone is not being protected by the summer closure period as fishing mortality is generally high. The highest fishing mortality was seen in 1989 on the 3 year old scallops in the inside zone. This high F (1.77) is attributed to the fear expressed by fishermen of losing the resource to the high natural mortality seen at that time. This level of F, four times F_{max}, indicates the fishing power of this fleet.

The abundance of scallops in both areas in 1994 is the lowest on record (1983 to 1994). The greatest decline in numbers is associated with the 1989 mortality event, which combined with catches, reduced the population by approximately 60% in the outside zone and by approximately 65% in the inside zone. In terms of biomass, approximately 6,160 metric tons of scallops were lost during the die-off (excluding catches for that year of 2,640 mt). Abundance has declined approximately 24% over both areas from 1993 to 1994, however, biomass was only reduced by approximately 6% (VPA estimates).

Exploitation Rate

Exploitation rates were calculated for ages 4 to 7, annually for each zone, according to the equation recommended for a Type 2 fishery (Ricker 1975). Exploitation rate (percentage removed by the fishery) has been generally higher for the inside zone, however, in 1994, exploitation was higher in the outside zone (Fig. 18). Peak exploitation rates were seen in 1991 in both zones, reaching its highest level of almost 50% in the inside zone. The exploitation rate for the inside zone is currently low, at roughly 10%, with the outside zone at 30%.

Catch Projections and Yield-per-Recruit Analyses

Catch projections (Mohn and Cook 1993) were made for the 1995 stock based on the standing stock in 1994, as determined from the VPA model. Projections beyond 1995 were not made, as our estimates of the number of pre-recruits are poor. The surveys provide reasonable abundance estimates of 3 year-old scallops, allowing about 6 months insight (from the date of a mid-year survey to the winter start of the projection year) into the strength of future recruitment to the exploited stock. Two year-old scallops, as has been shown, are not reliably represented in the survey catches, preventing more extended prediction of future year-class strengths.

The population matrices produced by the VPA were projected forward to the start of the following year (1995). Projected catch for 1995, fishing at $F_{0.1}$ and F_{max} levels, were calculated. The values of $F_{0.1}$ and F_{max} were produced using a Thompson-Bell yield-per-recruit model with meat weight at age and the partial recruitment pattern for 1994, calculated from the VPA, as input. Targeting by the fleet on the denser aggregations results in a dome-shaped partial recruitment pattern with the asymptote varying according to which of the age-classes is being targeted.

Results

Outside Zone

$F_{0.1}=0.33$ and $F_{max}=0.55$ were determined from a yield-per-recruit analysis using the 1994 partial recruitment pattern. The 1995 catch projection based on these values results in yields of 227 mt fishing at $F_{0.1}$ and 348 mt fishing at F_{max}.

While there is currently a small recruitment pulse moving through the VPA matrix (born in 1991, Table 18), these scallops will only be partially recruited in 1995 at age 4. It is likely that the fishery will continue to target the larger (older) animals in 1995, especially if they continue to provide a good price compared to the smaller ones.

Inside Zone

$F_{0.1}=0.27$ and $F_{max}=0.42$ were determined from a yield-per-recruit analysis using the 1994 partial recruitment pattern. The 1995 catch projection based on these values results in yields of 246 mt fishing at $F_{0.1}$ and 360 mt fishing at F_{max}.

The 1994 catch was comprised largely of 3,4 and 5 year old scallops. The dominant age-classes in the inside zone in 1995 will be 3,4, 5 and 6 year old scallops.

Discussion

Landings in 1994 were 211 mt for the outside zone with fishing mortality ranging from 0.26 to 0.44 for recruited age-classes. However, it should be noted that even with the relatively light effort taking place on these beds in 1994, in contrast to earlier years, fishing mortality was still close to F_{max}. Inside zone landings were 129 mt in 1994, and estimates of fishing mortality range from 0.12 to 0.17. This level of fishing is consistent with fishing below $F_{0.1}$.

Outlook

Abundance is at the lowest level recorded during the past decade (1983-1994), and biomass is also low (Fig. 19). The decline in stock density, from 1992 to 1994, seen in the research vessel survey is approximately 13%, which is less than the decline in landings. There have been no strong year-classes since the large recruitment pulses which entered the fishery in 1988 and 1989. Approximately 55% of the stock is over the age of 7, with over 20% of this aged 10+. In 1994, fishing mortality was near F_{max} in the outside zone, but closer to $F_{0.1}$ in the inside zone. However, our estimates of fishing mortality for this stock are poor. CPUE has fallen to an average of 2 kg/hm, which is very low, however prices remain very high, especially for the larger meats.

Given that this resource is now mature, and that the population structure is such that losses due to natural mortality exceed gains due to growth, there is no reason to restrict fishing effort from a yield-per-recruit point of view. The consequences of continued effort on this stock for recruitment over-fishing cannot be discerned, however, abundance is at the lowest level recorded during the past decade (1983-1994). Although stock-recruit relationships have seldom been proven for any invertebrate stock, it is logical that extremely low population levels would negatively effect recruitment. The population is already at the lowest level seen, and it is 10 years since the last big recruitment pulse. The question is: has damage to recruitment already been done, or can the population survive further reductions? With the recent collapse of the Nantucket scallop fishery (M. Sinclair, pers. comm.), we predict that the former scenario is the likely one.

Management Options

The crisis in the Bay of Fundy fishery was specifically addressed at the scientific Regional Invertebrate Working Group Meetings, held in Halifax on March 27-29, 1995. The recommendations of the meeting, considering all available documentation, were as follows:

1. That an area (20%) of the Digby grounds be closed to all forms of dragger fishing for a minimum of 10 years in order to protect a portion of the breeding population. This advice applies to all scallop stocks.
2. That this closure area should reflect historical nursery grounds as much as possible, and include a variety of settlement substrates.
3. That management and industry consider short-term area (2-3 year) closures to protect incoming strong year-classes from growth-overfishing. This may be achieved through a rotational fishing scenario.
4. That areas closed to protect incoming year-classes be monitored for changes in natural mortality.
5. That minimum meat/shell sizes be considered for each management unit by season (summer/winter), and that current size regulations be immediately increased.
6. That an attempt should be made in improve the yield per recruit possibly through point #5, or through other measures such as gear modification.

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Table 1. Time Period of Log Records Used for Catch Stratification for Each Survey Year.

Survey Year	Period Used to Define Catch Strata
1981	January 1, 1980 to May 1, 1981
1982	January 1, 1981 to May 1, 1982
1983	January 1, 1982 to May 1, 1983
1984	January 1, 1983 to May 1, 1984
1985	May 1, 1984 to May 1, 1985
1986	May 1, 1985 to May 1, 1986
1987	January 1, 1986 to June 1, 1987
1988	January 1, 1987 to December 31, 1987
1989	May 1, 1988 to May 1, 1989
1990	May 1, 1988 to May 1, 1989

Table 2. Number of Survey Stations by Area Strata with Fishing Zone* Indicated. A) Locations Catch Stratified, B) Locations Area and Zone Stratified. Shaded Areas Represent the Data Used for the Estimation of Biomass Using Delaunay Interpolation (see below).

A) Catch Stratified and Area and Zone Post-stratified.

Area Stratum	Fishing Zone	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Below Core	Centreville	3	19	20	20	21	16	4	0	9	16
Core	Gulliver's Head	22	20	28	23	29	22	23	15	15	25
	Digby Gut	41	49	35	49	39	37	45	34	52	35
	Delap Cove	4	9	14	12	18	14	13	18	15	30
Above Core	Parker's Cove	0	4	3	5	14	12	13	12	6	8
	Young Cove	0	0	0	0	0	3	10	10	7	4
	Hampton	0	0	0	0	8	11	11	11	6	16
Total		70	101	100	100	120	115	119	100	110	134

B) Area and Zone Stratified.

Area Stratum	Fishing Zone	1991	1992	1993	1994
Below Core	Centreville	10	12	12	11
Core	Gulliver's Head	27	23	20	17
	Digby Gut	29	27	21	21
	Delap Cove	19	12	17	15
Above Core	Parker's Cove	3	3	10	12
	Young Cove	2	4	10	10
	Hampton	10	8	10	10
Total		100	89	100	96

* Fishing zones and areas were post-stratified upon the catch stratified stations for the purpose of comparison and the realization of the geographic placement of the random stations.

Table 3. Number of Drags Sampled in the Biomass Survey, and Position in Gang by Year. 'L" Indicates Drags Lined with 38 mm Nylon Mesh, "U" Indicates Unlined Drags. Lower Case Letters for 1981 and 1982 Indicate that Either 1 or 7, 2 or 6, 3 or 5 Drags Were Sampled (i.e. 4 Drags/Tow Varying Position Between Tows).

Year	1	2	3	4	5	6	7
1981-82	l	u	l	U	l	u	l
1983-86	U	U	L	L	L	U	U
1987	-	-	L	L	L	U	-
1988	-	U	-	L	-	-	-
1989-94	L	U	L	U			

Table 4. Breakdown of the Commercial Catch Samples into Number of Scallop Meats Sampled by Area, Brackets Indicate the Number of Samples. Shaded Area Identifies the Data used to Calculate the VPAs for the "Inside" and "Outside" Zones (Fig. 1A, see below).

Year	< 6 miles	6-15.9 miles	> 16 miles	Brier Island	Unknown	Total
1983	66 (1)	9597 (123)	0 (0)	191 (2)	427 (5)	10281 (131)
1984	4708 (93)	18894 (221)	1372 (11)	0 (0)	131 (2)	25105 (327)
1985	1463 (32)	15907 (200)	1432 (13)	0 (0)	213 (2)	19015 (247)
1986	1809 (30)	12768 (124)	1905 (15)	0 (0)	112 (1)	16594 (170)
1987	3215 (29)	8463 (70)	623 (5)	0 (0)	117 (1)	12418 (105)
1988	5703 (65)	22847 (169)	0 (0)	0 (0)	0 (0)	28550 (234)
1989	2776 (38)	19571 (167)	8070 (49)	0 (0)	164 (1)	30581 (255)
1990	2313 (44)	8034 (82)	2183 (16)	57 (1)	1290 (13)	13877 (156)
1991	573 (16)	4861 (66)	634 (5)	1905 (15)	501 (6)	8474 (108)
1992	3667 (64)	4268 (55)	4876 (51)	2957 (33)	0 (0)	15768 (203)
1993	4902 (87)	9606 (133)	5378 (66)	3298 (37)	776 (9)	23960 (332)
1994	1671(24)	3073(42)	1112(17)	4630(70)	1021(13)	11507(166)

Table 5. Breakdown of the Commercial Catch Samples into Number of Meats Sampled by Area by Quarter of the Year. Shading Indicates Portion of the Data Set Used for VPA Analyses.

Area	Jan.-March	April-June	July-Sept.	Oct.-Dec.	Year
< 6 miles	0	0	66	0	1983
	0	1,590	918	2,200	1984
	0	571	83	809	1985
	0	287	324	1,198	1986
	0	0	0	3,215	1987
	0	1,185	0	4,518	1988
	0	103	871	1,802	1989
	0	164	905	1,244	1990
	0	0	0	573	1991
	0	0	532	3,135	1992
	2,620	300	293	1,689	1993
	447	137	0	1,087	1994
6-15.9 miles	0	5,016	4,581	0	1983
	0	9,239	9,655	0	1984
	0	5,600	10,307	0	1985
	0	4,564	7,659	545	1986
	0	686	5,627	2,150	1987
	0	8,433	14,063	351	1988
	0	10,609	8,962	0	1989
	0	2,759	5,180	95	1990
	0	2,475	2,215	171	1991
	0	268	1,560	2,440	1992
	3,153	3,250	1,664	1,539	1993
	841	679	1,443	110	1994
> 16 miles	0	0	0	0	1983
	0	206	1,166	0	1984
	0	270	1,162	0	1985
	0	1,201	704	0	1986
	0	359	264	0	1987
	0	0	0	0	1988
	0	107	7,963	0	1989
	0	574	1,609	0	1990
	0	365	269	0	1991
	0	0	2,760	2,116	1992
	2,051	1,826	1,171	330	1993
	0	656	456	0	1994

Table 6. Breakdown of the Commercial Catch Samples into Number of Samples, Number of Vessels and the Percentage of Samples from 2, 3, and 4 Vessels by Year.

Year	# samples	# vessels	% samples from 2 vessels	% samples from 3 vessels	% samples from 4 vessels
1983	131	12	44.3	59.5	71.8
1984	327	16	32.1	41.6	49.8
1985	247	17	41.7	53.0	61.1
1986	170	17	42.4	52.9	61.2
1987	105	16	32.4	41.9	49.5
1988	234	12	26.9	39.3	50.4
1989	255	15	30.6	43.5	55.7
1990	156	14	32.7	44.2	52.6
1991	108	12	36.1	51.9	63.0
1992	203	19	20.7	30.1	39.4
1993	332	29	34.3	49.7	57.5
1994	166	14	32.5	48.2	58.4

Table 7. Percentage of Vessels Submitting Fishing Log Information by Year.

Year	% Log Compliance
1981	95.6
1982	95.5
1983	96.1
1984	92.7
1985	95.7
1986	85.1
1987	55.0
1988	17.6
1989	14.6
1990	13.8
1991	29.0
1992	48.5
1993	63.6
1994	84.0

Table 8. Estimated Catches (mt) of Scallop Meat Derived from Percentages of Log Information from Each Zone Applied to the Statistics Branch Sales Slip Landings. Shading Indicates Portion of the Data Set Used for VPA.

Year	< 6 mi.	6-15.9 mi.	> 16 mi.	German /Lurcher	Brier Island	Georges Bank	Browns Bank	Total (mt)
1980	320.4	226.3	11.7	108.5	163.3	0.0	46.9	877.3
1981	436.7	176.1	35.8	246.5	240.4	288.7	25.5	1,449.6
1982	489.8	201.8	51.7	150.4	203.6	0.8	8.8	1,106.9
1983	404.7	339.8	62.9	42.0	45.8	0.0	0.0	895.2
1984	313.1	254.5	89.5	37.9	28.5	0.0	0.0	723.6
1985	272.8	285.6	119.7	1.9	12.7	14.4	4.6	711.6
1986	98.6	115.6	32.9	59.6	3.6	194.1	61.1	566.3
1987*	214.6	157.0	52.8	1.6	0.0	696.6	0.0	1,122.7
1988	1,901.1	1,006.7	96.8	0.0	0.0	8.4	0.0	3,013.0
1989	1,450.1	1,194.3	1,279.6	0.0	0.0	0.0	0.0	3,924.0
1990	491.3	591.6	1,328.1	0.0	0.0	0.0	0.0	2,411.0
1991	596.8	476.6	297.8	189.0	260.9	0.0	0.0	1,821.0
1992	331.0	374.3	419.9	459.3	367.5	0.0	0.0	1,952.0
1993	194.2	330.6	354.8	544.2	402.1	0.0	0.0	1,827.0
1994†	128.7	211.2	78.9	595.8	645.0	0.0	0.0	1,660.0

* In September 1986 the Inshore/Offshore Agreement between fleet sectors formally restricted the inshore fleet from fishing below latitude 43°40' N. The phase in period allowed the inshore fleet 548 mt from Georges Bank in 1987.
† Data for 1994 is preliminary.

Table 9. Breakdown of the Commercial Landings of the Full Bay Licence-Holders into Metric Tonnes of Meats Landed by Area by Quarter of the Year. Shading Indicates Portion of the Data Set Used for VPA Analyses.

Area	Jan.-March	April-June	July-Sept.	Oct.-Dec.	Year
< 6 miles	70	92	2	156	1980
	144	71	16	206	1981
	134	65	29	262	1982
	108	93	31	173	1983
	85	66	27	134	1984
	63	70	32	108	1985
	43	15	6	35	1986
	0	0	1	213	1987
	437	196	11	1,256	1988
	888	304	3	256	1989
	37	70	103	281	1990
	210	125	56	206	1991
	84	66	11	170	1992
	49	31	18	96	1993
	19	9	20	81	1994
6-15.9 miles	5	128	90	3	1980
	4	62	106	4	1981
	1	73	124	3	1982
	3	178	154	5	1983
	9	104	133	8	1984
	8	141	135	2	1985
	13	50	50	2	1986
	35	37	70	15	1987
	7	210	749	41	1988
	100	549	450	95	1989
	159	246	142	45	1990
	72	179	168	57	1991
	81	136	95	63	1992
	56	104	104	66	1993
	39	35	93	45	1994
> 16 miles	3	4	1	4	1980
	3	13	13	6	1981
	1	9	22	20	1982
	5	17	28	13	1983
	9	10	33	37	1984
	25	26	63	5	1985
	11	15	6	1	1986
	9	18	12	13	1987
	33	20	38	6	1988
	312	234	322	411	1989
	496	379	305	148	1990
	94	71	74	59	1991
	126	127	102	65	1992
	90	124	61	79	1993
	23	13	27	16	1994

Table 10. Catch, Effort and CPUE for (A) the Inside (< 6 mile) and (B) the Outside (6-15.9 mile) Scallop Fishing Zones, Off Digby. CPUE is Calculated From Class 1 (complete) Log Data.

(A) Inside Zone (< 6 miles)

Year	Class 1 Catch (mt)	Class 1 Effort (hm)	CPUE	Total Catch (mt)	Total Effort (1000 hm)
1976	34.8	7,191	4.83	-	-
1977	150.5	18,577	8.10	-	-
1978	193.3	23,665	8.17	-	-
1979	189.1	25,762	7.34	-	-
1980	263.9	33,122	7.97	320.4	40.2
1981	322.1	39,585	8.14	436.7	53.7
1982	371.1	50,810	7.30	489.8	67.1
1983	291.9	61,305	4.76	404.7	85.0
1984	261.5	74,606	3.51	313.1	89.2
1985	196.6	74,256	2.65	272.6	102.9
1986	55.0	25,917	2.12	98.6	46.5
1987	41.7	2,466	16.91	214.6	12.7
1988	158.5	9,389	16.88	1,901.1	112.6
1989	111.6	7,619	14.65	1,450.1	99.0
1990	61.7	11,365	5.43	491.3	90.5
1991	115.8	24,109	4.80	596.8	124.3
1992	112.8	34,162	3.30	331.0	100.3
1993	102.1	39,199	2.60	194.2	74.7
1994	55.2	27,094	2.04	128.7	63.1

(B) Outside Zone (6-15.9 miles)

Year	Class 1 Catch (mt)	Class 1 Effort (hm)	CPUE	Total Catch (mt)	Total Effort (1000 hm)
1976	17.7	4,794	3.69	-	-
1977	118.5	20,711	5.72	-	-
1978	159.2	28,814	5.53	-	-
1979	133.3	30,055	4.44	-	-
1980	185.7	30,958	6.00	226.3	37.7
1981	132.3	24,107	5.49	176.1	32.1
1982	156.8	26,963	5.82	201.8	34.7
1983	234.7	63,513	3.70	339.8	91.8
1984	209.4	76,539	2.74	254.5	92.9
1985	213.7	90,509	2.36	285.6	121.0
1986	62.8	28,751	2.18	115.6	53.0
1987	39.4	12,820	3.07	157.0	51.1
1988	89.2	12,838	6.95	1,006.7	144.8
1989	96.1	12,679	7.58	1,194.3	157.6
1990	57.3	10,249	5.59	591.6	105.8
1991	63.7	16,729	3.81	476.6	125.1
1992	86.1	27,750	3.10	374.3	120.7
1993	71.5	30,799	2.32	330.6	142.5
1994	56.2	28,343	1.98	211.2	106.7

Table 11. Annual Numbers (x 10^3) of Scallops-at-Height (5 mm Size Intervals) Prorated to 7-Gang Drags and Standardized to an 800 m Tow Length and Summated over all Survey Tows, for the Digby Bed Inside of 6 miles (A) and from 6-15.9 miles (B). The Percentage of Clappers (dead, empty shells) of the Total Catch Found During the Survey is Given for the Years 1984-1994.

(A) < 6miles

Size	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
10-15	0	0	25	0	0	16	18	0	0	0	0	0	0	42
15-20	0	17	248	0	0	138	53	0	0	0	0	30	134	48
20-25	28	50	669	28	0	1,784	717	226	32	36	27	130	508	363
25-30	33	90	781	28	45	10,299	6,641	474	69	85	33	85	254	653
30-35	113	296	226	116	77	30,496	20,862	372	196	151	84	112	287	837
35-40	324	266	184	162	95	43,370	42,156	118	643	89	214	48	127	456
40-45	809	229	381	328	106	32,696	55,270	243	1,297	116	438	85	247	360
45-50	1,105	129	675	655	114	11,738	37,159	3,210	3,259	111	234	133	418	375
50-55	912	72	704	1,074	193	3,508	14,477	8,203	6,149	350	331	311	461	683
55-60	1,307	236	939	1,171	159	1,149	11,658	25,607	8,795	436	147	230	468	768
60-65	790	204	529	772	184	850	21,757	34,075	9,060	303	200	269	197	547
65-70	3,738	976	1,238	798	301	952	52,665	72,291	7,171	1,225	311	810	404	943
70-75	4,090	1,319	1,665	684	611	688	61,187	63,236	5,062	2,127	461	662	481	919
75-80	3,385	2,098	1,329	646	995	984	84,160	43,705	7,326	3,465	544	677	474	345
80-85	1,786	4,017	858	1,421	1,566	854	37,052	38,143	22,478	5,550	1,076	650	919	432
85-90	3,700	4,171	1,358	2,056	1,819	1,152	8,251	56,145	36,054	5,385	1,904	541	1,393	737
90-95	7,607	4,062	2,515	2,324	1,819	1,679	3,133	64,455	36,643	5,668	3,193	1,058	1,794	1,185
95-100	8,030	4,353	3,710	2,824	1,686	2,012	1,911	39,491	38,773	6,754	4,343	2,252	1,927	819
100-105	5,830	4,423	3,933	3,062	1,786	2,124	1,363	16,846	31,052	10,883	3,534	2,527	2,114	1,753
105-110	5,049	4,746	4,156	3,657	2,201	2,414	1,517	5,568	19,518	12,077	4,493	3,397	2,522	2,412
110-115	5,308	4,784	3,759	3,907	2,326	1,835	1,670	2,398	10,174	10,491	4,810	4,144	2,889	2,578
115-120	6,112	5,374	4,156	3,404	2,735	1,831	1,944	1,049	4,167	5,565	4,807	3,536	3,694	2,675
120-125	6,497	4,687	4,175	3,085	2,597	1,653	1,490	1,416	1,626	2,585	3,264	3,464	2,776	1,774
125-130	6,022	3,875	3,184	2,537	2,086	1,227	1,750	581	1,037	1,169	1,734	1,931	2,352	1,451
130-135	4,852	3,323	2,488	2,398	1,580	759	1,209	637	404	405	932	1,227	1,597	1,046
135-140	1,354	1,673	1,014	1,085	582	451	220	338	60	40	87	18	555	178
140-145	964	473	709	859	473	370	267	85	0	18	0	109	321	109
145-150	61	226	384	253	242	160	167	147	0	0	0	0	70	88
150-155	66	70	33	205	61	57	53	45	0	0	0	0	67	18
155-160	28	45	29	45	7	21	0	102	0	0	0	0	0	0
160-165	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165-170	0	12	0	9	7	0	0	0	0	0	0	0	0	0
total	79,900	56,296	46,054	39,593	26,453	157,267	470,777	479,206	251,045	75,084	37,201	28,436	29,450	24,594
% clappers	-	-	-	5.3	3.0	2.0	2.4	2.2	34.2	66.5	29.4	11.8	10.4	5.3

Table 11. cont'd. Annual Numbers (x 10^3) of Scallops-at-Height (5 mm Size Intervals) Prorated to 7-Gang Drags and Standardized to an 800 m Tow Length and Summated over all Survey Tows, for the Digby Bed Inside of 6 miles (A) and from 6-15.9 miles (B). The Percentage of Clappers (dead, empty shells) of the Total Catch Found During the Survey is Given for the Years 1984-1994.

(B) 6-15.9 miles

Size	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
10-15	0	0	11	0	0	87	0	56	0	0	0	72	0	18
15-20	0	0	115	0	0	894	188	136	0	0	18	49	49	61
20-25	38	0	93	31	39	6,114	589	79	19	37	24	152	58	276
25-30	176	87	77	47	85	16,859	1,416	28	32	10	47	43	44	299
30-35	436	0	121	141	101	21,427	3,142	84	103	31	162	98	58	255
35-40	872	81	282	240	107	10,888	4,025	855	362	47	262	23	140	232
40-45	1,199	103	513	416	193	3,700	5,152	1,972	419	225	142	103	169	569
45-50	1,100	143	720	616	215	1,924	7,920	2,912	665	382	536	218	91	1,062
50-55	1,190	400	987	600	400	1,629	16,994	5,328	1,011	468	242	503	151	1,302
55-60	1,770	714	1,186	923	378	1,381	36,211	11,110	903	627	251	776	118	1,394
60-65	1,347	419	921	636	474	1,300	47,029	16,770	530	796	93	405	69	332
65-70	2,533	2,166	1,416	1,087	907	1,620	33,382	23,062	3,380	1,630	369	1,554	329	661
70-75	1,815	1,844	1,330	959	1,044	1,401	9,661	22,758	3,985	1,951	689	1,393	654	654
75-80	2,293	2,328	1,774	1,564	1,463	1,639	3,571	67,138	6,583	2,524	838	1,290	596	840
80-85	3,085	4,307	3,153	2,756	2,147	2,692	3,292	49,905	22,321	8,030	2,562	1,606	2,184	1,205
85-90	3,864	4,745	4,980	3,546	3,849	3,887	3,885	55,065	22,808	8,954	3,512	2,758	3,641	1,141
90-95	5,442	6,618	7,314	5,084	4,505	4,546	4,249	24,169	24,211	11,235	5,529	4,978	4,257	1,987
95-100	9,088	7,667	10,140	6,505	5,901	4,194	4,841	5,567	32,216	10,333	6,545	6,653	3,921	1,935
100-105	12,156	8,844	11,901	7,494	8,282	6,289	5,638	2,258	20,583	10,614	7,764	8,773	3,823	3,628
105-110	13,933	12,312	13,247	7,531	9,099	7,023	4,872	2,052	6,946	9,762	9,441	8,741	5,188	4,387
110-115	13,558	13,802	11,595	6,122	7,773	6,087	3,742	1,814	2,495	6,339	9,018	6,966	4,568	4,182
115-120	10,431	10,301	8,258	4,949	5,862	3,709	2,584	1,552	1,300	3,300	5,842	4,725	3,485	3,345
120-125	6,298	5,916	4,874	3,083	3,513	2,041	1,685	1,201	998	1,040	2,802	2,373	1,559	2,078
125-130	2,450	2,363	2,246	1,042	2,068	1,329	984	682	484	307	1,003	1,063	903	883
130-135	1,247	884	685	327	832	558	426	463	162	173	438	184	231	406
135-140	279	16	69	42	165	57	27	0	59	0	31	0	0	0
140-145	35	38	13	11	0	41	0	0	0	24	0	0	47	0
145-150	32	35	0	0	0	9	0	0	0	0	0	0	0	0
150-155	0	0	0	0	0	0	0	28	0	0	0	0	0	0
Total	96,667	86,133	88,021	55,752	59,402	113,325	205,505	297,044	152,575	78,839	58,160	55,499	36,333	33,132
% clappers	-	-	-	3.8	1.3	2.5	4.9	4.7	25.3	58.1	28.8	12.6	5.2	7.4

Table 12. Estimated Population Numbers (x 10^3) -at-Age Calculated from Delaunay Estimates of the Survey Data for the Core Area off Digby. The Area Covered by the Survey and the Relative Area are Represented From 1985-1993.

Age	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	402	117,786	57,174	3,101	583	186	639	276	485
3	1,056	26,937	98,326	35,242	7,127	967	748	1,083	755
4	2,267	4,762	139,202	75,479	8,332	2,530	905	2,558	1,106
5	4,506	5,810	31,968	192,702	34,017	7,200	3,315	1,889	4,664
6	7,181	6,436	5,933	53,675	42,298	11,098	7,790	3,743	6,060
7	8,617	6,732	5,091	7,456	21,715	12,991	8,046	5,049	4,159
8	8,732	6,179	4,275	2,746	5,056	8,805	7,893	5,063	4,268
9+	6,154	5,001	2,635	1,700	1,775	3,727	5,506	4,097	3,290
Total	38,915	179,643	344,604	372,101	120,903	47,504	34,842	23,578	24,787
Area	1,085	1,037	959	683	735	868	867	815	894
Rel. Area	1.00	0.96	0.88	0.63	0.68	0.80	0.80	0.75	0.82

Table 13. Annual Numbers (x 10^3) of Scallops-at-Age for the Digby Bed Inside 6 miles (A), From 6 - 15.9 miles (B) and for the Combined Areas (C), Calculated by the Slicing Method Applied to the Research Survey Numbers of Scallops-at-Height (Table 11).

(A) < 6miles

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	13	40	571	12	0	949	391	101	14	16	12	88	360	252
2	1,785	966	2,242	940	374	123,062	141,825	2,758	3,670	510	887	460	1,382	2,673
3	5,040	954	3,017	3,683	713	12,395	88,513	97,068	28,534	1,615	926	1,191	1,511	2,563
4	10,648	5,939	4,172	2,503	2,540	2,670	195,726	170,028	27,563	9,000	1,711	2,152	1,645	2,055
5	11,610	9,997	4,113	4,930	4,305	3,138	30,502	135,199	81,412	13,484	5,395	1,851	3,518	2,050
6	13,552	8,401	7,219	5,586	3,336	3,933	3,314	58,974	67,867	16,356	7,573	4,459	3,850	2,388
7	7,856	7,142	6,112	5,525	3,307	3,402	2,324	9,124	28,099	17,522	6,755	5,262	3,880	3,601
8	6,758	6,018	4,692	4,380	2,992	2,184	2,138	2,123	8,856	9,820	5,727	4,605	3,878	3,123
9	5,925	4,715	3,911	3,043	2,501	1,634	1,607	1,162	2,688	3,789	3,770	3,285	3,026	2,077
10+	16,713	12,125	10,004	8,989	6,382	3,901	4,439	2,669	2,344	2,972	4,443	5,079	6,398	3,808

(B) 6 - 15.9 miles

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	28	0	195	23	28	5,493	623	250	14	27	36	233	92	283
2	3,488	374	1,537	1,297	650	55,865	19,609	5063	1,402	600	1,007	465	492	2195
3	5,856	2,636	3,988	2,864	1,758	5,641	118,827	45,342	4,288	2,797	917	2,507	525	3648
4	6,446	6,738	4,896	4,014	3,699	4,780	31,343	118,602	19,878	8,035	2,587	4,020	2,160	2240
5	8,583	10,850	10,666	7,871	7,486	7,904	8,152	99,918	49,476	19,793	7,928	6,272	7,180	2916
6	13,317	12,093	15,288	9,989	9,187	7,260	7,678	18,094	46,982	17,313	10,288	10,238	6,541	3382
7	15,590	12,107	15,124	9,238	10,483	8,000	6,671	2,707	20,537	12,766	10,147	10,788	5,187	4734
8	12,865	11,884	11,866	6,613	8,096	6,273	4,216	1,843	5,207	8,120	8,670	7,636	4,655	4026
9	9,545	9,717	8,163	4,310	5,472	4,285	2,634	1,277	1,757	4,463	6,349	4,904	3,216	2944
10	20,949	19,732	16,296	9,534	12,541	7,825	5,755	3,950	3,036	4,928	10,234	8,435	6,284	6767

(C) Total Area

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	41	40	766	35	28	6,442	1,014	351	28	43	48	321	452	535
2	5,273	1,340	3,779	2,237	1,024	178,927	161,434	7,821	5,072	1,110	1,894	925	1,874	4,868
3	10,896	3,590	7,005	6,547	2,471	18,036	207,340	142,410	32,822	4,412	1,843	3,698	2,036	6,211
4	17,094	12,677	9,068	6,517	6,239	7,450	227,069	288,630	47,441	17,035	4,298	6,172	3,805	4,295
5	20,193	20,847	14,779	12,801	11,791	11,042	38,654	235,117	130,888	33,277	13,323	8,123	10,698	4,966
6	26,869	20,494	22,507	15,575	12,523	11,193	10,992	77,068	114,849	33,669	17,861	14,697	10,391	5,770
7	23,446	19,249	21,236	14,763	13,790	11,402	8,995	11,831	48,636	30,288	16,902	16,050	9,067	8,335
8	19,623	17,902	16,558	10,993	11,088	8,457	6,354	3,966	14,063	17,940	14,397	12,241	8,533	7,149
9	15,470	14,432	12,074	7,353	7,973	5,919	4,241	2,439	4,445	8,252	10,119	8,189	6,242	5,021
10	37,662	31,857	26,300	18,523	18,923	11,726	10,194	6,619	5,380	7,900	14,677	13,514	12,682	10,575

Table 14. Population Numbers (x 10^3)-at-Age Estimates and Resulting Estimates of Z Values Calculated From Slicing of Numbers-at-Height for the Inside Zone (A) and Outside Zone (B).

(A) Inside Zone < 6 miles

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	13	40	571	12	0	949	391	101	14	16	12	88	360	252
2	1,785	966	2,242	940	374	123,062	141,825	2,758	3,670	510	887	460	1,382	2,673
3	5,040	954	3,017	3,683	713	12,395	88,513	97,068	28,534	1,615	926	1,191	1,511	2,563
4	10,648	5,939	4,172	2,503	2,540	2,670	195,726	170,028	27,563	9,000	1,711	2,152	1,645	2,055
5	11,610	9,997	4,113	4,930	4,305	3,138	30,502	135,199	81,412	13,484	5,395	1,851	3,518	2,050
6	13,552	8,401	7,219	5,586	3,336	3,933	3,314	58,974	67,867	16,356	7,573	4,459	3,850	2,388
7	7,856	7,142	6,112	5,525	3,307	3,402	2,324	9,124	28,099	17,522	6,755	5,262	3,880	3,601
8	6,758	6,018	4,692	4,380	2,992	2,184	2,138	2,123	8,856	9,820	5,727	4,605	3,878	3,123
9	5,925	4,715	3,911	3,043	2,501	1,634	1,607	1,162	2,688	3,789	3,770	3,285	3,026	2,077
10+	16,713	12,125	10,004	8,989	6,382	3,901	4,439	2,669	2,344	2,972	4,443	5,079	6,398	3,808
Total	79,899	56,297	46,053	39,589	26,451	157,268	470,779	479,206	251,048	75,083	37,199	28,434	29,449	24,592

Zs estimated from above numbers, ages 5+ are fully recruited.

	82/81	83/82	84/83	85/84	86/85	87/86	88/87	89/88	90/89	91/90	92/91	93/92	94/93	Ave
1 vs 2	**-4.31**	**-4.03**	**-0.50**	**-3.44**		**-5.01**	**-1.95**	**-3.59**	**-3.60**	**-4.02**	**-3.65**	**-2.75**	**-2.00**	**-3.24**
2 vs 3	0.63	**-1.14**	**-0.50**	0.28	**-3.50**	0.33	0.38	**-2.34**	0.82	**-0.60**	**-0.29**	**-1.19**	**-0.62**	**-0.60**
3 vs 4	**-0.16**	**-1.47**	0.19	0.37	**-1.32**	**-2.76**	**-0.65**	1.26	1.15	**-0.06**	**-0.84**	**-0.32**	**-0.31**	**-0.38**
4 vs 5	**-0.06**	0.37	**-0.17**	**-0.54**	**-0.21**	**-2.44**	0.37	0.74	0.71	0.51	**-0.08**	**-0.49**	**-0.22**	**-0.11**
5 vs 6	0.32	0.33	**-0.31**	0.39	0.09	**-0.05**	**-0.66**	0.69	1.60	0.58	0.19	**-0.73**	0.39	0.22
6 vs 7	0.64	0.32	0.27	0.52	**-0.02**	0.53	**-1.01**	0.74	1.35	0.88	0.36	0.14	0.07	0.37
7 vs 8	0.27	0.42	0.33	0.61	0.42	0.46	0.09	0.03	1.05	1.12	0.38	0.31	0.22	0.44
8 vs 9	0.36	0.43	0.43	0.56	0.61	0.31	0.61	**-0.24**	0.85	0.96	0.56	0.42	0.62	0.50
9^+ vs 10^+	0.62	0.52	0.44	0.63	0.82	0.22	0.82	0.49	0.53	0.42	0.48	0.27	0.91	0.55
Ave 5-10	0.44	0.40	0.23	0.54	0.38	0.29	**-0.03**	0.34	1.08	0.79	0.39	0.08	0.44	0.42
6^+ vs 5^+	0.49	0.42	0.27	0.56	0.42	0.27	**-0.51**	0.64	1.33	0.82	0.39	0.15	0.49	0.44

Table 14. cont'd. Population Numbers (x 10^3)-at-Age Estimates and Resulting Estimates of *Z* Values Calculated From Slicing of Numbers-at-Height for the Inside Zone (A) and Outside Zone (B).

(B) Outside Zone 6-15.9 miles

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	28	0	195	23	28	5,493	623	250	14	27	36	233	92	283
2	3,488	374	1,537	1,297	650	55,865	19,609	5,063	1,402	600	1,007	465	492	2,195
3	5,856	2,636	3,988	2,864	1,758	5,641	118,827	45,342	4,288	2,797	917	2,507	525	3,648
4	6,446	6,738	4,896	4,014	3,699	4,780	31,343	118,602	19,878	8,035	2,587	4,020	2,160	2,240
5	8,583	10,850	10,666	7,871	7,486	7,904	8,152	99,918	49,476	19,793	7,928	6,272	7,180	2,916
6	13,317	12,093	15,288	9,989	9,187	7,260	7,678	18,094	46,982	17,313	10,288	10,238	6,541	3,382
7	15,590	12,107	15,124	9,238	10,483	8,000	6,671	2,707	20,537	12,766	10,147	10,788	5,187	4,734
8	12,865	11,884	11,866	6,613	8,096	6,273	4,216	1,843	5,207	8,120	8,670	7,636	4,655	4,026
9	9,545	9,717	8,163	4,310	5,472	4,285	2,634	1,277	1,757	4,463	6,349	4,904	3,216	2,944
10	20,949	19,732	16,296	9,534	12,541	7,825	5,755	3,950	3,036	4,928	10,234	8,435	6,284	6,767
Total	96,667	86,132	88,019	55,753	59,401	113,325	205,507	297,045	152,576	78,840	58,163	55,498	36,333	33,136

Zs estimated from above numbers, ages 5+ are fully recruited.

	82/81	83/82	84/83	85/84	86/85	87/86	88/87	89/88	90/89	91/90	92/91	93/92	94/93	Ave
1 vs 2	**-2.59**		**-1.89**	**-3.34**	**-7.60**	**-1.27**	**-2.10**	**-1.72**	**-3.76**	**-3.62**	**-2.56**	**-0.75**	**-3.17**	**-2.86**
2 vs 3	0.28	**-2.37**	**-0.62**	**-0.30**	**-2.16**	**-0.75**	**-0.84**	0.17	**-0.69**	**-0.43**	**-0.91**	**-0.12**	**-2.00**	**-0.83**
3 vs 4	**-0.14**	**-0.62**	**-0.01**	**-0.26**	**-1.00**	**-1.72**	0.00	0.82	**-0.63**	0.08	**-1.48**	0.15	**-1.45**	**-0.48**
4 vs 5	**-0.52**	**-0.46**	**-0.47**	**-0.62**	**-0.76**	**-0.53**	**-1.16**	0.87	0.00	0.01	**-0.89**	**-0.58**	**-0.30**	**-0.42**
5 vs 6	**-0.34**	**-0.34**	0.07	**-0.15**	0.03	0.03	**-0.80**	0.75	1.05	0.65	**-0.26**	**-0.04**	0.75	0.11
6 vs 7	0.10	**-0.22**	0.50	**-0.05**	0.14	0.08	1.04	**-0.13**	1.30	0.53	**-0.05**	0.68	0.32	0.33
7 vs 8	0.27	0.02	0.83	0.13	0.51	0.64	1.29	**-0.65**	0.93	0.39	0.28	0.84	0.25	0.44
8 vs 9	0.28	0.38	1.01	0.19	0.64	0.87	1.19	0.05	0.15	0.25	0.57	0.86	0.46	0.53
9^+ vs 10+	0.44	0.59	0.94	0.10	0.83	0.74	0.75	0.54	**-0.03**	**-0.09**	0.05	0.75	0.34	0.51
Ave 5-10	-0.08	**-0.14**	0.45	**-0.19**	0.19	0.27	0.46	**-0.17**	0.48	0.20	0.05	0.42	0.21	0.17
6^+ vs 5^+	0.21	0.14	0.67	0.04	0.46	0.43	0.23	0.50	0.98	0.39	0.24	0.62	0.41	0.41

Table 15. The Numbers of Scallops-at-Height by Age Calculated for the Outside Zone in 1988. Samples For Ageing Were Collected During the June 1988 Survey, and a Partial Age-Length Key (Ages 5-10) was Constructed and Applied.

Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	84
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	855
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,972
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,911
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,328
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,110
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16,770
70	0	23,061	0	0	0	0	0	0	0	0	0	0	0	0	23,061
75	0	11,378	11,378	0	0	0	0	0	0	0	0	0	0	0	22,757
80	0	28,482	38,655	0	0	0	0	0	0	0	0	0	0	0	67,137
85	0	3,424	39,630	6,849	0	0	0	0	0	0	0	0	0	0	49,904
90	0	0	24,655	30,408	0	0	0	0	0	0	0	0	0	0	55,064
95	0	0	3,173	19,775	1,220	0	0	0	0	0	0	0	0	0	24,169
100	0	0	168	3,289	1,518	506	84	0	0	0	0	0	0	0	5,566
105	0	0	0	694	1,215	231	115	0	0	0	0	0	0	0	2,257
110	0	0	0	56	170	1,253	170	284	56	56	0	0	0	0	2,051
115	0	0	0	0	88	176	442	530	309	221	44	0	0	0	1,813
120	0	0	0	0	0	67	0	404	438	236	269	101	33	0	1,551
125	0	0	0	0	0	0	0	0	231	415	231	277	0	46	1,201
130	0	0	0	0	0	0	0	0	0	170	113	170	113	113	682
135	0	0	0	0	0	0	0	0	0	0	61	154	61	185	462
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	66,348	117,662	61,074	4,213	2,235	813	1,220	1,036	1,100	720	703	209	345	297,044

Table 16. Estimated Population Numbers (x 10^3)-at-Age for the Outside Zone from Application of Partial Age-Height Keys, Along with resulting *Z* estimates.

Age	1983	1984	1985	1986	1987	1988
5	13,535	12,629	5,938	9,346	7,184	61,074
6	19,619	11,920	8,829	6,623	7,258	4,213
7	20,725	8,184	7,506	7,067	4,533	2,235
8	15,509	5,591	8,564	6,742	4,860	813
9	6,631	4,050	7,203	3,872	3,365	1,220
10	1,961	2,038	5,806	1,897	2,470	1,036

*Z*s calculated from above population numbers, all ages used are assumed to be fully recruited.

	84/83	85/84	86/85	87/86	88/87	Average
5 vs 6	0.13	0.36	**-0.11**	0.25	0.53	0.23
6 vs 7	0.87	0.46	0.22	0.38	1.18	0.62
7 vs 8	1.31	**-0.05**	0.11	0.37	1.72	0.69
8 vs 9	1.34	**-0.25**	0.79	0.69	1.38	0.79
9 vs 10	1.18	**-0.36**	1.33	0.45	1.18	0.76
Ave	0.97	0.03	0.47	0.43	1.20	0.62
5-9/6-10	0.87	0.11	0.37	0.40	1.05	0.56

Table 17. Total Numbers (x 10^3)-at-Height in Survey Areas Broken Down into Size Modes for the Inside and Outside Zones. Mode 1 Represents 2 Year-Old Scallops, with each Subsequent Mode Representing an Additional Year. The Final Mode in each Year Represents Scallops of that Age and Older. Resulting Estimates of Z Values are Listed for each Zone.

A) Inside zone < 6 miles

Mode	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	42	488	1,761	278	313	31,221	14	1,203	324	352	25	390	1,255	2,521
2	4,882	666	2,375	2,786	616	97,275	182,318	26,429	11,812	1,052	1,518	882	1,803	2,314
3	11,405	2,865	3,564	2,879	2,031	7,132	274,440	236,057	30,779	2,692	759	1,787	1,261	2,392
4	4,807	17,588	9,864	4,925	5,750	2,365	2,952	190,326	71,193	18,033	3,141	1,794	3,813	473
5	25,172	3,487	10,762	5,852	1,431	5,188	8,333	17,620	108,426	17,606	11,086	4,501	4,083	4,026
6	3,722	14,942	3,098	12,391	6,222	9,295	2,104	5,056	21,118	24,480	5,698	5,248	2,819	4,842
7	29,870	16,261	14,629	10,479	10,088	4,792	617	2,415	7,396	10,868	14,972	13,832	14,414	8,023
Total	79,900	56,297	46,053	39,590	26,451	157,268	470,778	479,206	251,048	75,083	37,199	28,434	29,448	24,591

Zs calculated from above numbers, modes 4+ are fully recruited.

	82/81	83/82	84/83	85/84	86/85	87/86	88/87	89/88	90/89	91/90	92/91	93/92	94/93	Average
2/1	**-2.76**	**-1.58**	**-0.46**	**-0.80**	**-5.74**	**-1.76**	**-7.55**	**-2.28**	**-1.18**	**-1.46**	**-3.56**	**-1.53**	**-0.61**	**-2.41**
3/2	0.53	**-1.68**	**-0.19**	0.32	**-2.45**	**-1.04**	**-0.26**	**-0.15**	1.48	0.33	**-0.16**	**-0.36**	**-0.28**	**-0.30**
4/3	**-0.43**	**-1.24**	**-0.32**	**-0.69**	**-0.15**	0.88	0.37	1.20	0.53	**-0.15**	**-0.86**	**-0.76**	0.98	**-0.05**
5/4	0.32	0.49	0.52	1.24	0.10	**-1.26**	**-1.79**	0.56	1.40	0.49	**-0.36**	**-0.82**	**-0.05**	0.06
6/5	0.52	0.12	**-0.14**	**-0.06**	**-1.87**	0.90	0.50	**-0.18**	1.49	1.13	0.75	0.47	**-0.17**	0.38
$7^+/6^+$	0.73	0.76	0.53	0.82	1.22	3.13	0.12	0.01	0.96	0.86	0.40	0.28	0.76	0.81
$4^+/3^+$	**-0.36**	0.36	0.22	0.44	0.16	0.72	0.29	0.77	1.21	0.75	0.34	0.08	0.42	0.47
ave4^+	**-0.28**	0.42	0.15	0.33	**-0.17**	0.91	**-0.20**	0.40	1.10	0.58	**-0.02**	**-0.21**	0.38	0.30

Table 17. cont'd. Total Numbers (x 10^3)-at-Height in Survey Areas Broken Down into Size Modes for the Inside and Outside Zones. Mode 1 Represents 2 Year-Old Scallops, with each Subsequent Mode Representing an Additional Year. The Final Mode in each Year Represents Scallops of that Age and Older. Resulting Estimates of Z Values are Listed for each Zone.

B) Outside zone 6-15.9 miles

Mode	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	3,982	439	3,366	2,453	1,351	50,818	2,263	303	38	51	127	359	159	661
2	7,127	2,597	4,539	3,253	2,434	13,633	27,156	9,211	3,952	1,223	1,364	835	732	2,718
3	7,936	11,243	6,813	6,795	6,200	4,867	135,780	44,,880	7,632	4,100	826	4,109	839	2,427
4	13,113	17,534	18,852	12,764	8,647	7,275	7,631	167,431	39,969	18,554	3,888	3,666	4,873	3,261
5	29,112	16,173	20,568	9,884	6,461	8,834	8,822	59,798	80,545	21,284	23,324	8,883	10,657	11,462
6	24,605	31,602	5,922	4,716	30,348	9,082	14,807	7,304	16,345	17,833	16,947	21,545	7,568	9,952
7	10,792	6,544	27,959	15,890	3,959	5,393	9,049	8,118	4,095	15,794	11,688	312	5,370	897
8						13,422						15,789	6,134	1,759
Total	96,667	86,132	88,019	55,755	59,400	113,324	205,508	297,045	152,576	78,839	58,164	55,498	36,332	33,137

Zs calculated from above numbers, modes 4+ are fully recruited.

	82/81	83/82	84/83	85/84	86/85	87/86	88/87	89/88	90/89	91/90	92/91	93/92	94/93	Average
2/1	0.43	**-2.34**	0.03	0.01	**-2.31**	0.63	**-1.40**	**-2.57**	**-3.47**	**-3.29**	**-1.88**	**-0.71**	**-2.84**	**-1.52**
3/2	**-0.46**	**-0.96**	**-0.40**	**-0.64**	**-0.69**	**-2.30**	**-0.50**	0.19	**-0.04**	0.39	**-1.10**	0.00	**-1.20**	**-0.59**
4/3	**-0.79**	**-0.52**	**-0.63**	**-0.24**	**-0.16**	**-0.45**	**-0.21**	0.12	**-0.89**	0.05	**-1.49**	**-0.17**	**-1.36**	**-0.52**
5/4	**-0.21**	**-0.16**	0.65	0.68	**-0.02**	**-0.19**	**-2.06**	0.73	0.63	**-0.23**	**-0.83**	**-1.07**	**-0.86**	**-0.23**
6/5	**-0.08**	1.00	1.47	**-1.12**	**-0.34**	**-0.52**	0.19	1.30	1.51	0.23	0.08	0.16	0.07	0.30
$7/6^+$	1.69	0.31	0.76	1.65	1.73	0.47	1.08	1.33	0.26	1.06	3.99	1.39	2.13	1.37
$8^+/7^+$				**-1.22**						**-0.30**	0.97	1.88	0.33	
$4^+/3^+$	0.36	0.28	0.88	0.06	0.30	0.30	**-0.62**	0.88	0.94	0.35	0.18	0.52	0.36	0.37
ave4^+	0.15	0.16	0.56	0.24	0.00	**-0.17**	**-0.25**	0.87	0.38	0.28	0.29	0.26	0.37	0.24

Table 18. Total Numbers of Scallops-at-Age in the Catch, Survey Data and VPA model for the Outside Fishing Zone (6-15.9 miles) off Digby. Fishing Mortality and the Residuals of the VPA Model are presented as well as Biomass-at-age estimates for the VPA and survey.

Sliced Catch Numbers-at-Age (x 10^3)

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	8	2	1	0	6	1	21	2	7	7	0	4
4	1,478	772	1,286	314	875	1,914	9,986	6,661	3,548	551	794	216
5	2,684	4,070	4,298	3,272	3,779	5,550	64,806	53,315	17,879	4,317	6,074	3,188
6	1,680	7,301	5,328	5,501	3,105	5,123	41,090	49,956	17,186	8,164	8,236	5,721
7	1,295	7,058	4,805	5,153	1,939	1,852	8,442	19,297	10,558	8,367	5,887	3,801
8	629	4,615	2,957	3,477	1,099	965	2,195	4,945	5,423	6,160	3,087	2,692
9	392	2,602	1,670	2,081	529	421	1,178	1,946	2,402	4,020	1,915	2,067
10	163	806	640	875	155	157	572	715	804	1,428	811	1,199
11	121	587	472	648	113	116	427	526	588	1,049	601	899
12	468	691	827	1,289	211	355	884	720	947	2,134	1,849	2,576
Total	8,916	28,505	22,283	22,612	11,811	16,455	129,601	138,083	59,342	36,198	29,255	22,361

Sliced Research Vessel Survey Numbers-at-Age (x 10^6)

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.19	0.02	0.03	5.49	0.62	0.25	0.01	0.03	0.04	0.23	0.09	0.28
2	1.54	1.30	0.65	55.86	19.61	5.06	1.40	0.60	1.01	0.46	0.49	2.20
3	3.99	2.86	1.76	5.64	118.83	45.34	4.29	2.80	0.92	2.51	0.52	3.65
4	4.90	4.01	3.70	4.78	31.34	118.60	19.88	8.04	2.59	4.02	2.16	2.24
5	10.67	7.87	7.49	7.90	8.15	99.92	49.48	19.79	7.93	6.27	7.18	2.92
6	15.29	9.99	9.19	7.26	7.68	18.09	46.98	17.31	10.29	10.24	6.54	3.38
7	15.12	9.24	10.48	8.00	6.67	2.71	20.54	12.77	10.15	10.79	5.19	4.73
8	11.87	6.61	8.10	6.27	4.22	1.84	5.21	8.12	8.67	7.64	4.65	4.03
9	8.16	4.31	5.47	4.29	2.63	1.28	1.76	4.46	6.35	4.90	3.22	2.94
10	4.44	2.65	3.14	2.00	1.39	0.83	0.71	1.80	3.15	2.54	1.87	1.79
11	3.32	1.99	2.36	1.49	1.04	0.62	0.52	1.33	2.35	1.90	1.40	1.34
12	8.54	4.90	7.04	4.33	3.33	2.50	1.81	1.81	4.74	3.99	3.02	3.63
Total	88.02	55.75	59.40	113.32	205.51	297.04	152.58	78.84	58.16	55.50	36.33	33.14

Table 18. cont'd. Total Numbers of Scallops-at-Age in the Catch, Survey Data and VPA model for the Outside Fishing Zone (6-15.9 miles) off Digby. Fishing Mortality and the Residuals of the VPA Model are presented as well as Biomass-at-age estimates for the VPA and survey.

VPA Model Numbers-at-Age (x 10^3)

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	75,245.9	496,546.3	749,453.4	642,662.9	79,825.8	46,334.5	38,506.7	22,603.0	5,855.4	26,076.4	0.0	0.0
2	39,915.6	68,085.3	449,293.7	678,133.5	581,505.4	72,229.4	41,925.2	34,842.3	20,452.0	5,298.2	23,594.9	0.0
3	38,578.5	36,117.1	61,606.1	406,537.7	613,600.6	526,167.9	65,355.9	37,935.5	31,526.6	18,505.8	4,794.0	21,349.6
4	30,776.0	34,899.9	32,677.9	55,742.6	367,850.4	555,202.7	476,095.5	59,116.6	34,324.0	28,519.4	16,737.9	4,337.8
5	27,959.1	26,441.4	30,844.5	28,345.1	50,139.3	332,012.1	500,547.2	187,198.7	47,154.7	27,683.0	25,281.0	14,389.5
6	23,891.6	22,745.7	20,053.3	23,821.1	22,534.9	41,772.8	295,138.0	162,184.9	42,114.1	25,660.2	20,,942.6	17,097.6
7	15,248.1	20,020.3	13,635.9	13,076.5	16,321.5	17,437.1	32,924.7	93,793.8	34,086.2	21,758.9	15452.3	11,115.0
8	7,801.9	12,565.3	11,401.7	7,767.5	6,930.2	12,923.9	14,015.7	21,761.5	25,829.2	20,799.8	11,729.0	8,381.7
9	7,278.0	6,460.9	6,979.6	7,504.1	3,720.4	5,225.7	10,776.0	10,594.2	14,986.9	18,212.5	12,960.5	7,676.1
10	4,015.2	6,212.6	3,370.5	4,726.7	4,810.9	2,863.6	4,327.5	8,630.2	7,734.8	11,275.8	12,655.6	9,905.4
11	2,329.5	3,478.1	4,854.7	2,441.3	3,444.3	4,205.2	2,441.2	3,371.1	7,128.5	6,233.9	8,844.0	10,679.6
12	5,841.6	1,993.1	2,588.7	3,944.2	1,592.4	3,009.2	3,694.8	1,803.2	2,549.8	5,890.4	4,642.9	7,430.8
Total	278,881.0	735,566.0	1,386,760.0	1,874,703.3	1,752,276.2	1,619,384.1	1,485,748.2	643,834.9	273,742.2	215,914.3	157,634.8	112,363.1

Fishing Mortality

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.10	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.05	0.02	0.04	0.01	0.00	0.00	0.03	0.13	0.12	0.02	0.05	0.05
5	0.11	0.18	0.16	0.13	0.08	0.02	0.23	0.59	0.51	0.18	0.29	0.26
6	0.08	0.41	0.33	0.28	0.16	0.14	0.25	0.66	0.56	0.41	0.53	0.43
7	0.09	0.46	0.46	0.53	0.13	0.12	0.31	0.39	0.39	0.52	0.51	0.44
8	0.09	0.49	0.32	0.64	0.18	0.08	0.18	0.27	0.25	0.37	0.32	0.41
9	0.06	0.55	0.29	0.34	0.16	0.09	0.12	0.21	0.18	0.26	0.17	0.33
10	0.04	0.15	0.22	0.22	0.03	0.06	0.15	0.09	0.12	0.14	0.07	0.14
11	0.06	0.20	0.11	0.33	0.04	0.03	0.20	0.18	0.09	0.19	0.07	0.09
12	0.09	0.45	0.41	0.42	0.15	0.13	0.29	0.54	0.49	0.48	0.54	0.45
Ave 4-7	0.08	0.27	0.25	0.24	0.09	0.07	0.21	0.44	0.39	0.28	0.35	0.30

Residuals

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
4	0.22	-0.12	-0.12	-0.42	-0.43	0.49	-0.73	0.10	-0.49	0.08	0.01	1.40
5	0.46	0.24	0.03	0.15	-0.41	0.17	-0.43	-0.18	-0.16	-0.03	0.25	-0.10
6	0.54	0.34	0.34	-0.10	-0.05	0.18	-0.36	-0.56	-0.18	0.24	0.06	-0.45
7	0.71	0.13	0.64	0.45	-0.16	-1.13	0.35	-0.73	-0.35	0.23	-0.17	0.04
Ave 4-7	0.48	0.15	0.22	0.02	-0.26	-0.07	-0.29	-0.34	-0.29	0.13	0.04	0.22

Table 18. cont'd. Total Numbers of Scallops-at-Age in the Catch, Survey Data and VPA model for the Outside Fishing Zone (6-15.9 miles) off Digby. Fishing Mortality and the Residuals of the VPA Model are presented as well as Biomass-at-age estimates for the VPA and survey.

VPA Biomass-at-age estimates (tonnes meat weight).

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0	1	2	1	0	0	0	0	0	0	0	0
2	13	22	145	219	188	23	14	11	7	2	8	0
3	64	60	102	670	1,012	868	108	63	52	31	8	35
4	122	138	130	221	1,459	2,202	1,888	234	136	113	66	17
5	191	181	211	194	343	2,273	3,426	1,281	323	189	173	99
6	235	224	198	235	222	412	2,908	1,598	415	253	206	168
7	194	254	173	166	207	221	418	1,190	433	276	196	141
8	119	191	173	118	105	196	213	331	393	316	178	127
9	126	112	121	130	64	90	187	183	260	315	224	133
10	77	118	64	90	92	55	82	164	147	215	241	189
11	48	71	99	50	70	86	50	69	146	128	181	218
12	126	43	56	85	34	65	80	39	55	127	100	160
Total	1,315	1,415	1,474	2,179	3,796	6,491	9,374	5,163	2,367	1,965	1,581	1,287

Sliced Survey Biomass-at-age estimates (tonnes meat weight).

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	18	6	2	0	0	0	0	0	1
3	7	5	3	9	196	75	7	5	2	4	1	6
4	19	16	15	19	124	470	79	32	10	16	9	9
5	73	54	51	54	56	684	339	135	54	43	49	20
6	151	98	91	72	76	178	463	171	101	101	64	33
7	192	117	133	102	85	34	261	162	129	137	66	60
8	180	100	123	95	64	28	79	123	132	116	71	61
9	141	75	95	74	46	22	30	77	110	85	56	51
10	85	50	60	38	26	16	13	34	60	48	36	34
11	68	41	48	31	21	13	11	27	48	39	29	28
12	184	106	152	93	72	54	39	39	102	86	65	78
Total	1100	662	771	605	772	1,576	1,321	805	748	675	446	381

Table 19. Total Numbers of Scallops-at-Age in the VPA-Tuned Catch and Survey Data, and VPA model for the Inside Fishing Zone (< 6 miles) off Digby. Fishing Mortality and the Residuals of the VPA Model are presented as well as Biomass-at-age estimates for the VPA and survey.

VPA-Tuned Catch Numbers-at-Age (x 10^3)

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	603	411	190	1,190	7,219	59,170	101,920	709	16,001	4,916	102	1,325
4	4,367	2,712	1,842	3,126	16,004	108,919	76,085	7,420	11,896	11,145	2,201	3,311
5	5,084	4,299	1,904	1,443	190	21,564	10,343	8,748	3,285	2,763	2,228	2,130
6	4,509	3,162	2,705	808	62	2,434	7,243	5,659	3,008	2,309	2,173	868
7	3,855	2,688	2,089	605	74	1,034	1,602	3,093	4,092	1,272	1,940	733
8	3,113	1,248	1,186	222	70	677	1,171	898	1,883	920	607	253
9	766	1,137	378	94	27	399	678	593	896	383	332	71
10	400	190	502	18	11	106	310	389	510	190	150	45
11	127	145	70	40	2	39	71	193	427	120	91	32
12	247	273	399	23	28	40	237	287	1,459	939	390	149
Total	23,069	16,266	11,266	7,569	23,686	194,381	199,661	27,989	43,458	24,958	10,214	8,916

VPA-Tuned Research Vessel Survey Numbers-at-Age (x 10^6)

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	3.46	2.39	0.44	27.92	38.19	34.52	15.12	0.93	0.55	0.82	1.82	4.58
2	1.38	1.17	0.35	107.27	150.82	3.93	5.32	0.45	0.95	0.34	2.90	4.58
3	4.97	3.32	2.72	4.12	240.32	227.08	34.36	8.32	1.90	2.58	3.61	7.48
4	4.90	5.25	4.53	3.47	29.09	158.88	98.59	14.27	6.22	2.56	5.85	6.63
5	7.17	6.42	3.41	3.67	2.36	45.45	64.48	19.26	8.18	4.22	5.40	7.94
6	6.11	5.40	3.89	3.24	2.04	4.05	26.47	19.50	6.16	6.67	6.13	7.40
7	4.59	4.21	2.95	2.69	2.14	1.57	2.68	8.02	6.33	3.77	6.85	8.27
8	5.18	2.39	2.22	1.38	2.09	1.22	1.62	1.63	2.77	3.03	4.06	6.67
9	2.27	3.60	1.07	0.94	1.12	1.06	1.15	1.03	1.38	1.52	3.60	5.45
10	2.42	1.21	2.48	0.34	0.81	0.54	0.80	0.86	0.95	0.99	3.11	5.36
11	1.83	2.24	0.70	1.64	0.28	0.45	0.29	0.61	1.02	0.77	3.01	5.28
12	1.77	2.01	1.69	0.58	1.51	0.46	0.16	0.21	0.79	1.16	3.16	5.37
Total	46.05	39.59	26.45	157.27	470.78	479.21	251.05	75.08	37.20	28.43	49.51	75.02

Table 19. cont'd. Total Numbers of Scallops-at-Age in the VPA-Tuned Catch and Survey Data, and VPA model for the Inside Fishing Zone (< 6 miles) off Digby. Fishing Mortality and the Residuals of the VPA Model are presented as well as Biomass-at-age estimates for the VPA and survey.

VPA Model Numbers-at-Age (x 10^3)

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	20,326.9	179,391.1	353,849.7	428,495.1	157,731.7	36,419.8	50,392.0	45,939.2	42,770.0	28,317.2	0.0	0.0
2	14,463.8	18,392.5	162,319.8	320,176.5	387,718.4	142,721.5	32,954.0	45,596.6	41,567.5	38,699.9	25,622.4	0.0
3	17,464.9	13,087.4	16,642.2	146,873.0	289,707.6	350,822.1	129,139.8	29,818.0	41,257.5	37,611.9	35,017.1	23,184.1
4	21,501.1	15,229.7	11,450.6	14,878.2	131,764.7	255,271.1	261,152.4	19,901.0	26,305.7	22,110.6	29,356.1	31,587.3
5	14,264.6	15,300.7	11,200.6	8,608.5	10,489.2	104,002.3	127,372.3	36,901.3	10,949.3	12,486.3	9,405.3	24,469.0
6	11,531.8	8,071.5	9,755.5	8,323.2	6,416.2	9,310.3	73,593.0	32,687.5	6,313.5	6,782.2	8,669.4	6,391.3
7	6,304.2	6,145.3	4,295.8	6,253.8	6,762.8	5,746.8	6,109.1	18,190.6	6,739.4	2,851.1	3,940.4	5,777.4
8	9,194.4	2,037.7	3,003.5	1,899.7	5,082.9	6,049.3	4,216.4	4,004.1	3,781.2	2,205.8	1,370.1	1,720.0
9	1,425.0	5,358.2	656.2	1,589.6	1,507.3	4,532.9	4,829.3	2,701.3	2,768.9	1,630.1	1,120.6	662.6
10	1,801.4	561.0	3,766.8	234.2	1,349.2	1,338.1	3,722.4	3,724.6	1,880.0	1,653.6	1,110.2	697.8
11	840.1	1,249.4	327.3	2,930.4	194.4	1,210.7	1,110.1	3,073.0	3,000.5	1,215.6	1,315.6	861.4
12	466.1	639.3	992.2	229.9	2,613.4	174.1	1,058.5	937.1	2,596.9	2,308.5	985.9	1,103.7
Total	119,584.3	265,463.9	578,260.2	940,492.1	1,001,337.8	917,599.0	695,649.3	243,474.4	189,930.5	157,872.9	117,913.0	96,454.6

Fishing Mortality

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.10	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00	0.00
3	0.04	0.03	0.01	0.01	0.03	0.20	1.77	0.03	0.52	0.15	0.00	0.06
4	0.24	0.21	0.19	0.25	0.14	0.60	0.76	0.50	0.65	0.75	0.08	0.12
5	0.47	0.35	0.20	0.19	0.02	0.25	0.16	0.57	0.38	0.26	0.29	0.10
6	0.53	0.53	0.34	0.11	0.01	0.32	0.20	0.38	0.69	0.44	0.31	0.15
7	1.03	0.62	0.72	0.11	0.01	0.21	0.32	0.37	1.02	0.63	0.73	0.14
8	0.44	1.03	0.54	0.13	0.01	0.13	0.35	0.27	0.74	0.58	0.63	0.17
9	0.83	0.25	0.93	0.06	0.02	0.10	0.16	0.26	0.42	0.28	0.37	0.12
10	0.27	0.44	0.15	0.09	0.01	0.09	0.09	0.12	0.34	0.13	0.15	0.07
11	0.17	0.13	0.25	0.01	0.01	0.03	0.07	0.07	0.16	0.11	0.08	0.04
12	0.80	0.59	0.55	0.11	0.01	0.27	0.27	0.39	0.88	0.55	0.53	0.15
Ave 4-7	0.57	0.43	0.36	0.16	0.04	0.34	0.36	0.45	0.68	0.52	0.35	0.13

Residuals

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
4	-0.34	0.06	0.18	-0.31	-0.42	0.84	0.97	0.93	-0.10	-0.76	-0.56	-0.49
5	0.18	-0.06	-0.46	-0.12	-0.85	-0.07	0.58	0.82	0.53	-0.32	0.22	-0.44
6	-0.07	0.16	-0.45	-0.59	-0.84	-0.38	-0.08	0.52	0.62	0.50	0.10	0.52
7	0.31	0.04	0.10	-0.67	-1.03	-1.08	-0.55	0.03	0.56	0.71	1.03	0.54
Ave 4-7	0.02	0.05	-0.16	-0.43	-0.79	-0.17	0.23	0.57	0.40	0.03	0.20	0.03

Table 19. cont'd. Total Numbers of Scallops-at-Age in the VPA-Tuned Catch and Survey Data, and VPA model for the Inside Fishing Zone (< 6 miles) off Digby. Fishing Mortality and the Residuals of the VPA Model are presented as well as Biomass-at-age estimates for the VPA and survey.

VPA Biomass-at-age estimates (tonnes meat weight).

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	2	19	37	45	16	4	5	5	4	3	0	0
2	10	12	107	211	255	94	22	30	27	25	17	0
3	85	64	81	718	1,415	1,714	631	146	202	184	171	113
4	211	150	112	146	1,294	2,506	2,564	195	258	217	288	310
5	199	213	156	120	146	1,449	1,774	514	153	174	131	341
6	211	147	178	152	117	170	1,344	597	115	124	158	117
7	140	137	96	139	151	128	136	405	150	64	88	129
8	238	53	78	49	131	156	109	104	98	57	35	44
9	41	155	19	46	44	131	140	78	80	47	32	19
10	57	18	119	7	43	42	117	117	59	52	35	22
11	28	42	11	99	7	41	37	104	101	41	44	29
12	17	23	35	8	93	6	38	33	92	82	35	39
Total	1,239	1,033	1,029	1,740	3,712	6,441	6,917	2,328	1,339	1,070	1,034	1,163

Tuned Survey Biomass-at-age estimates (tonnes meat weight).

Age	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0	0	0	3	4	4	2	0	0	0	0	0
2	1	1	0	71	99	3	4	0	1	0	2	3
3	24	16	13	20	1,174	1,109	168	41	9	13	18	37
4	48	52	45	34	286	1,560	968	140	61	25	57	65
5	100	89	47	51	33	633	898	268	114	59	75	111
6	112	99	71	59	37	74	484	356	113	122	112	135
7	102	94	66	60	48	35	60	179	141	84	153	184
8	134	62	57	36	54	31	42	42	72	78	105	173
9	66	104	31	27	32	31	33	30	40	44	104	158
10	76	38	78	11	26	17	25	27	30	31	98	169
11	62	75	24	55	9	15	10	20	34	26	101	178
12	63	71	60	21	53	16	6	7	28	41	112	190
Total	788	701	492	448	1,855	3,528	2,700	1,110	643	523	937	1,403

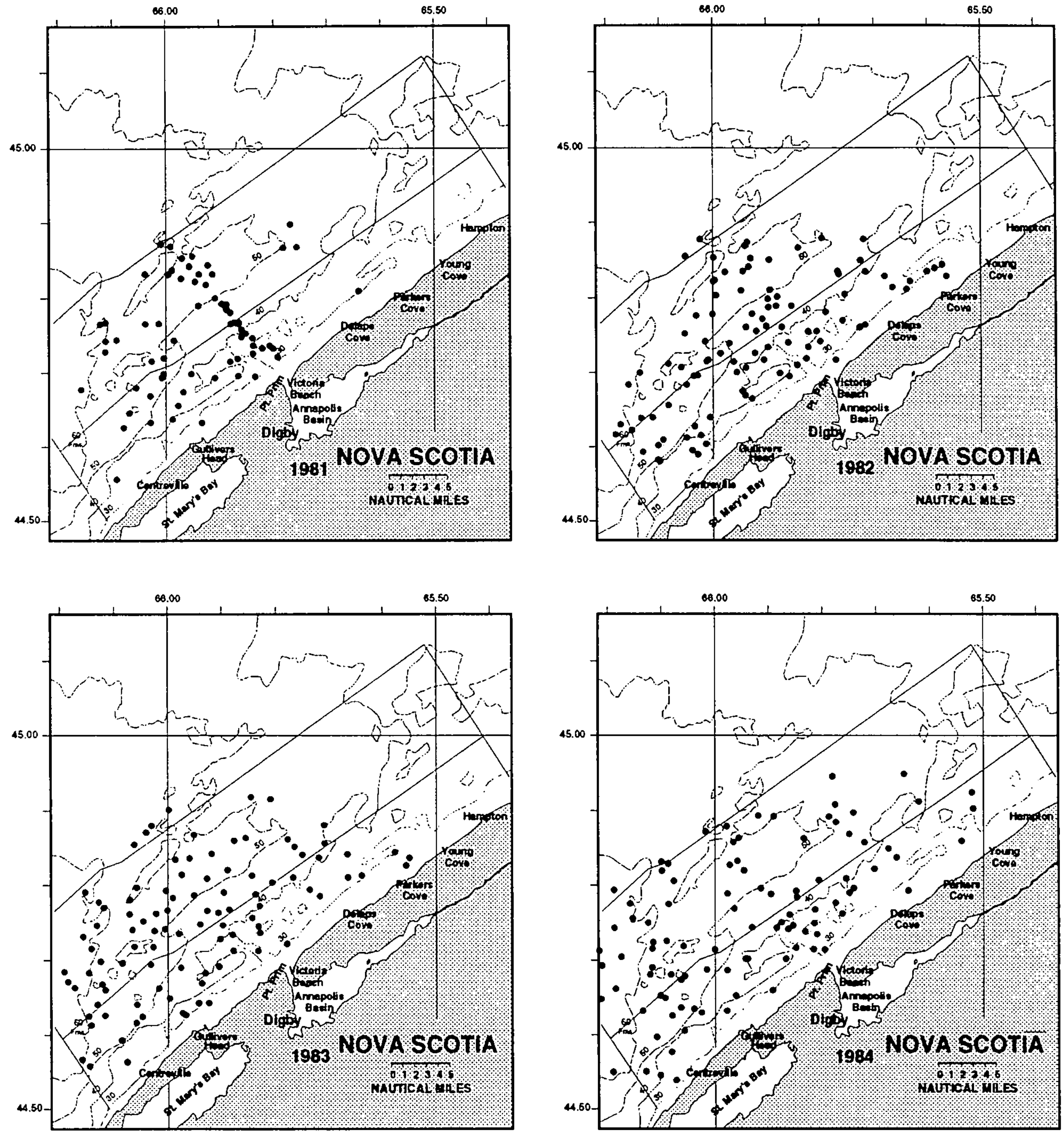


Figure 1A. Location of catch-stratified survey sampling stations from 1981 - 1990. The 6 mile line delineates the inside zone from the outside zone, which ends at the 16 mile line. These zones are defined for analytical purposes.

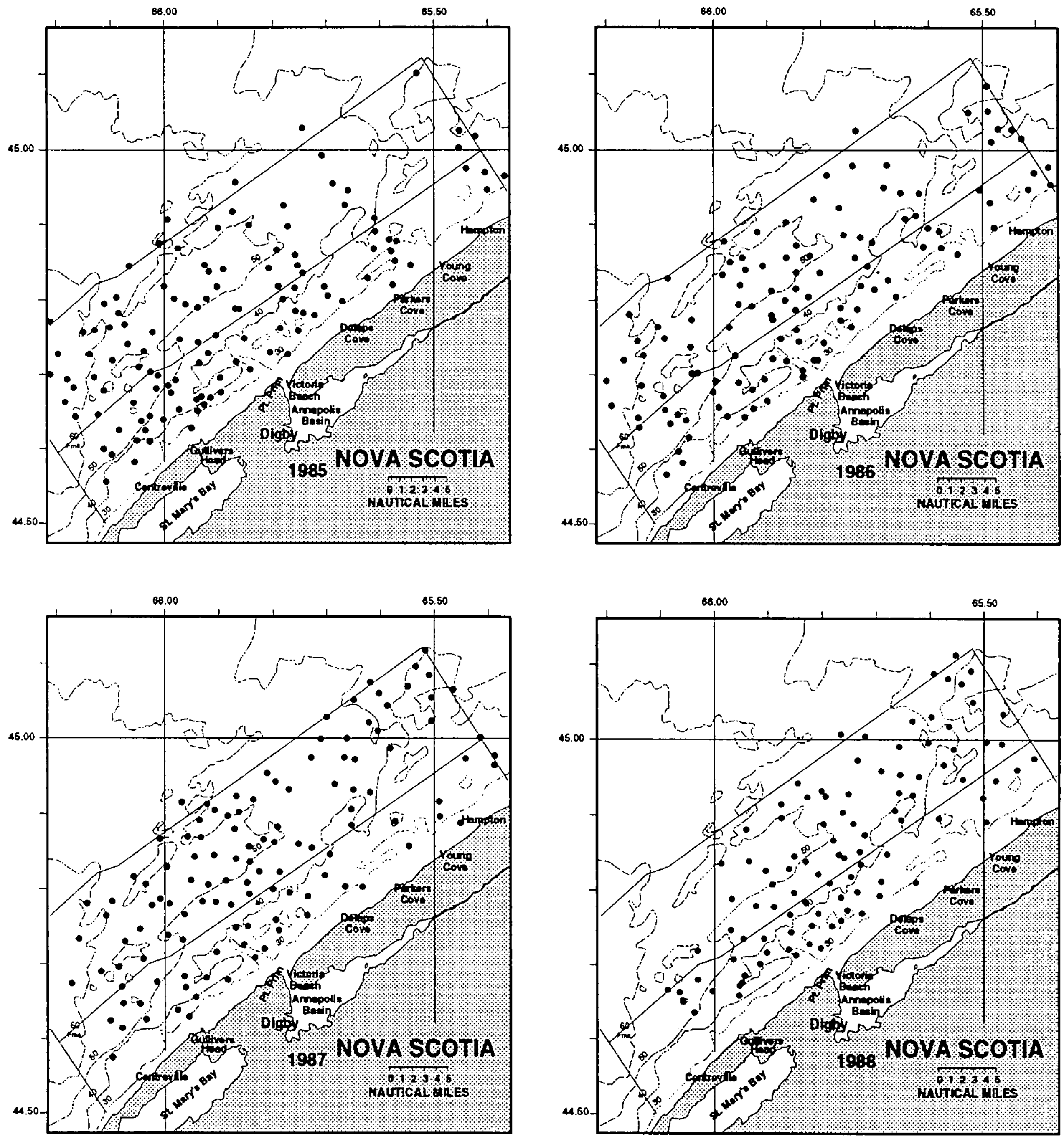


Figure 1A. cont'd. Location of catch-stratified survey sampling stations from 1981 - 1990. The 6 mile line delineates the inside zone from the outside zone, which ends at the 16 mile line. These zones are defined for analytical purposes.

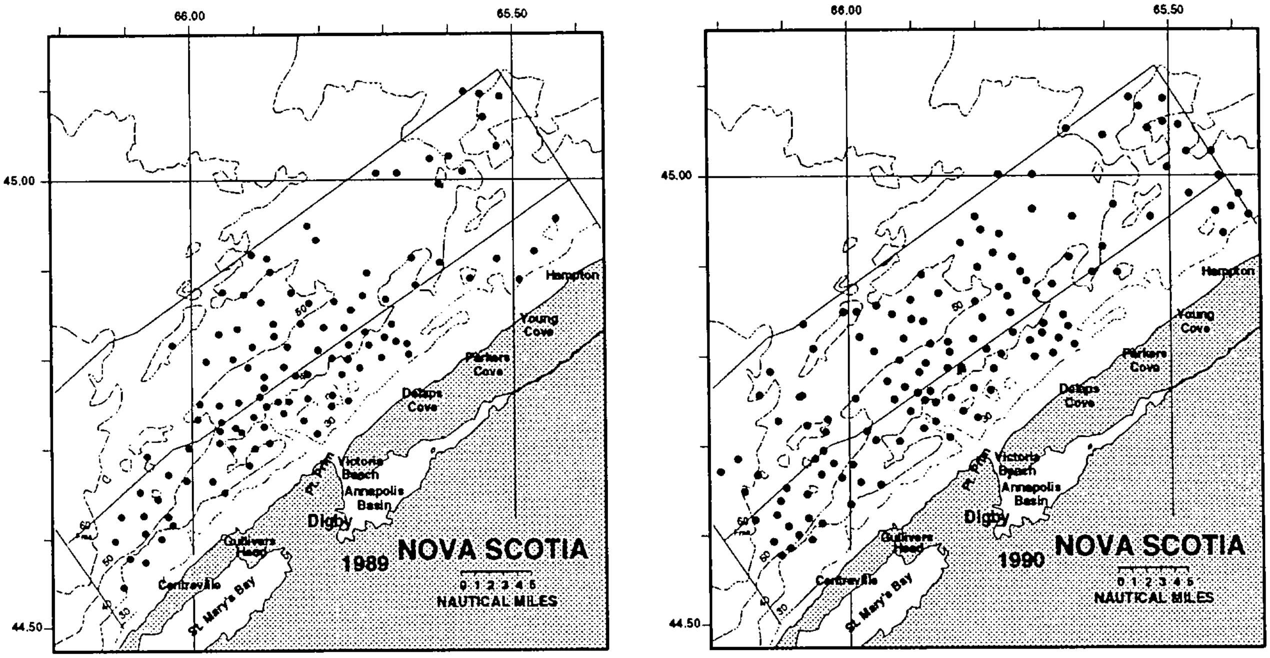


Figure 1A. cont'd. Location of catch-stratified survey sampling stations from 1981 - 1990. The 6 mile line delineates the inside zone from the outside zone, which ends at the 16 mile line. These zones are defined for analytical purposes.

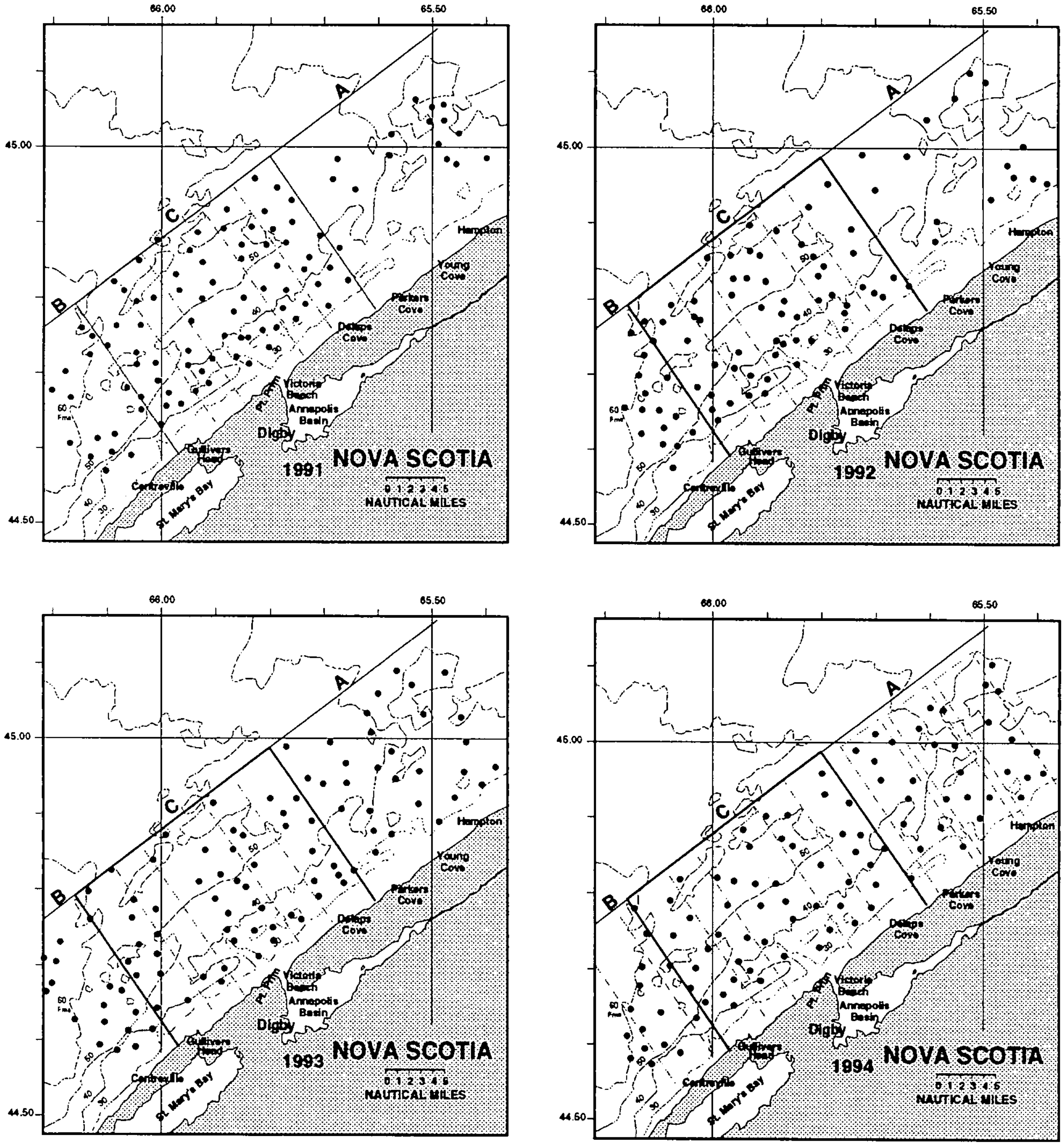


Figure 1B. Location of area stratified survey stations from 1991 - 1994. The fishing areas are defined by A (above), B (below) and C (core). The stations in the core area (C) were stratified by area and fishing zone. All fishing zones are illustrated on the 1994 survey map.

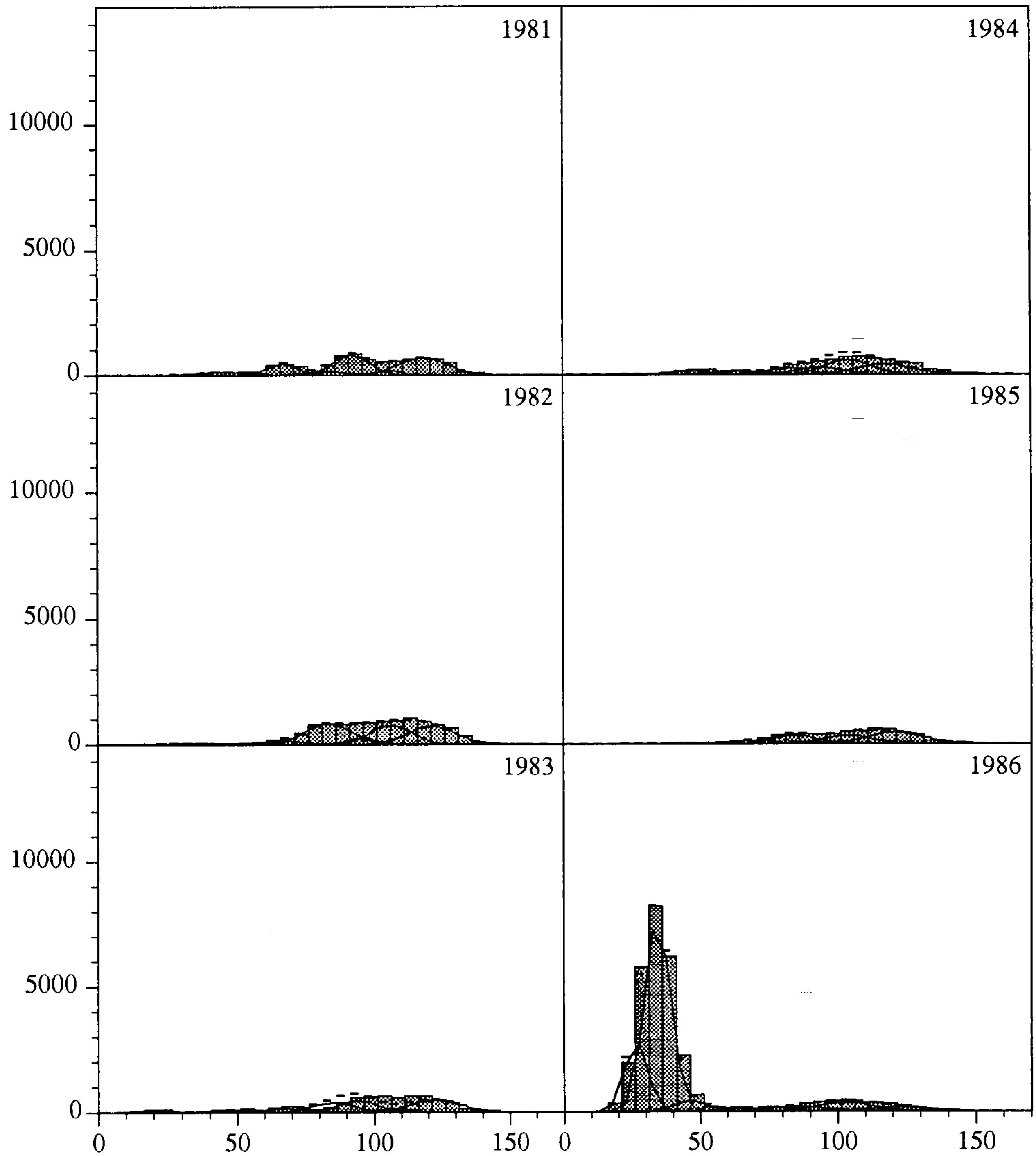


Figure 2A. Survey shell height frequencies for the inside zone with fitted modes (using Mix 3.1), and resulting frequencies (-).

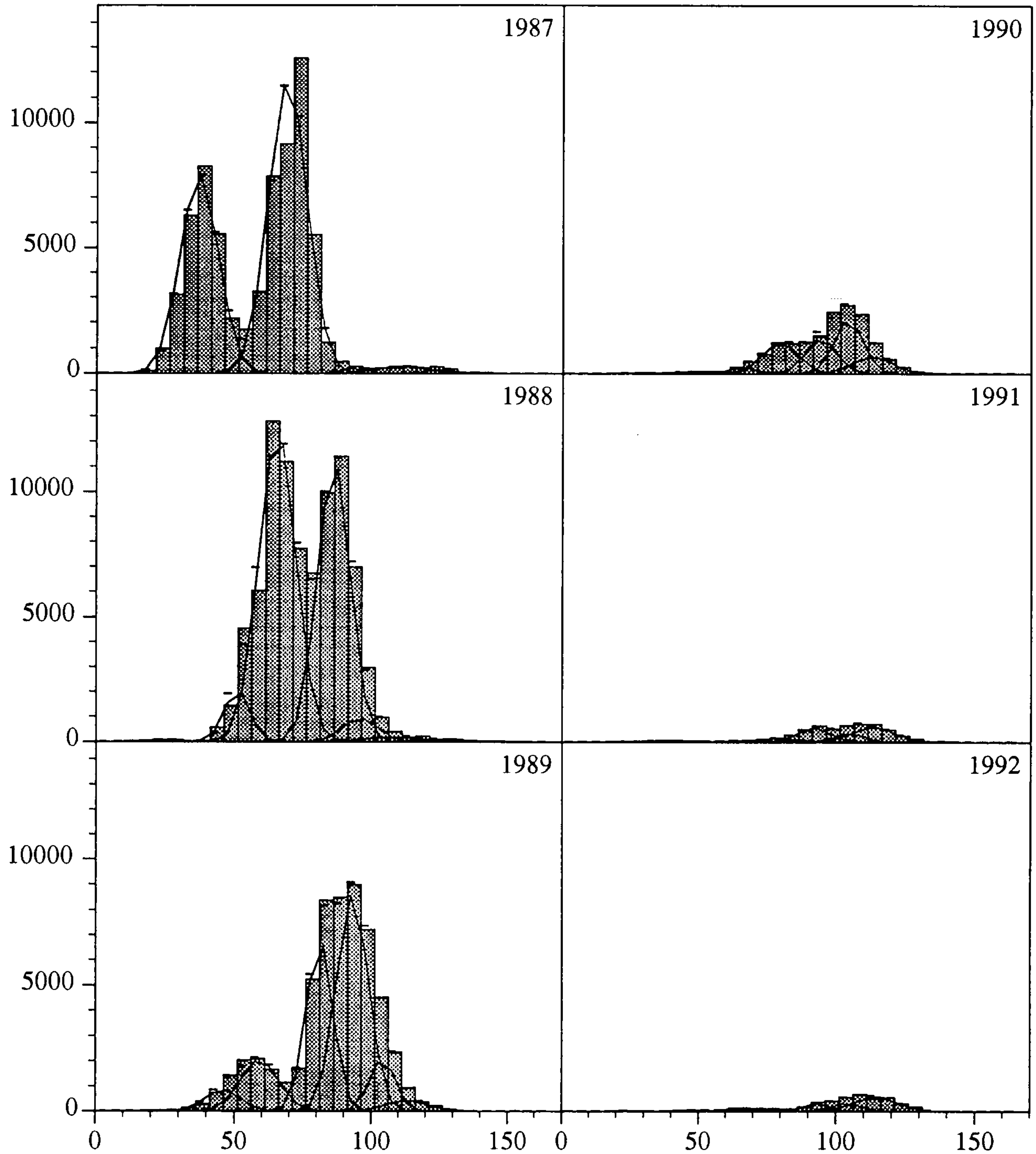


Figure 2A cont'd. Survey shell height frequencies for the inside zone with fitted modes (using Mix 3.1), and resulting frequencies (-).

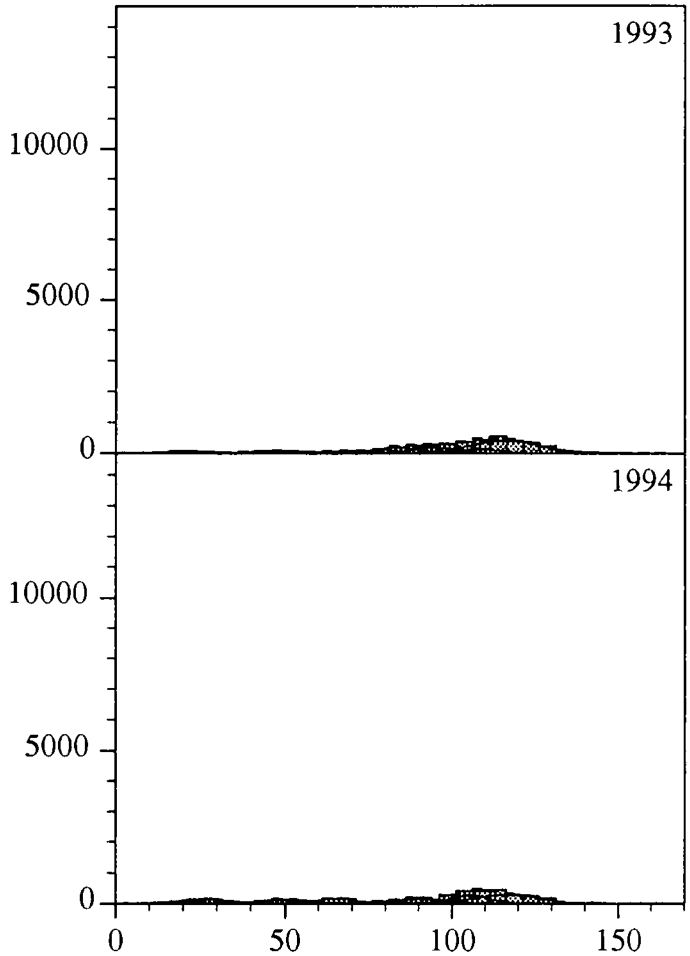


Figure 2A cont'd. Survey shell height frequencies for the inside zone with fitted modes (using Mix 3.1), and resulting frequencies (-).

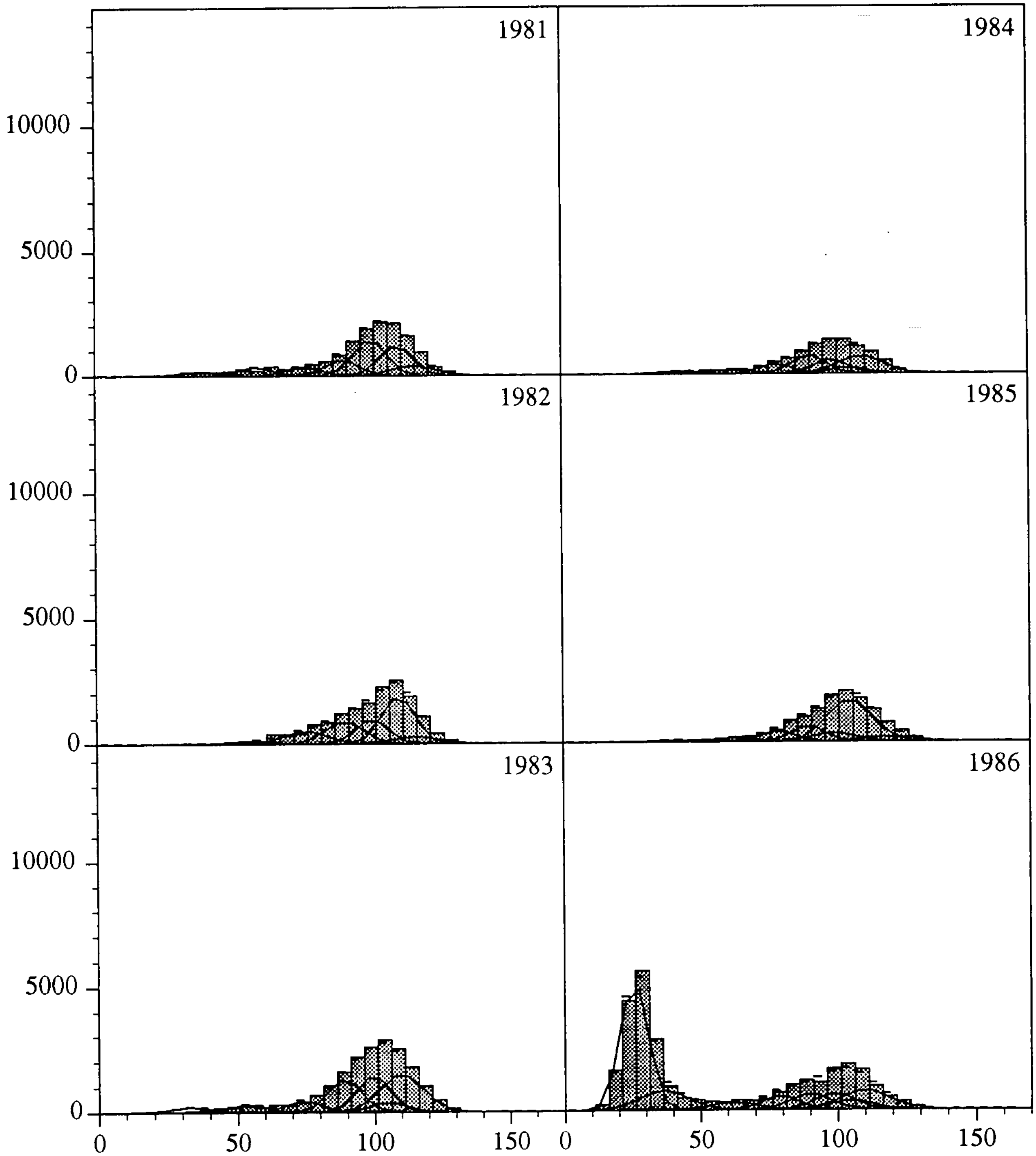


Figure 2B. Survey shell height frequencies for the outside zone with fitted modes (using Mix 3.1), and resulting frequencies (-).

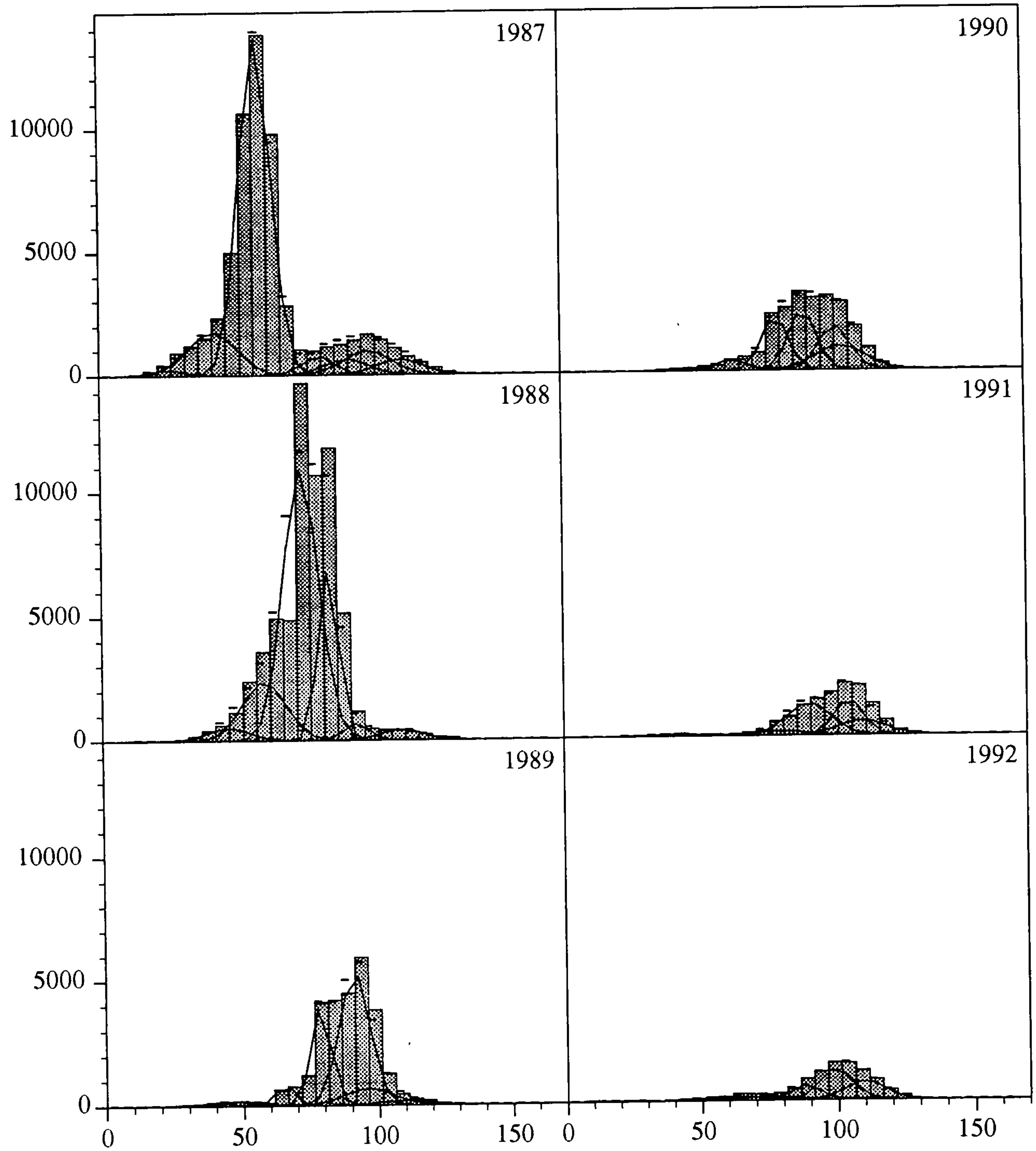


Figure 2B cont'd. Survey shell height frequencies for the outside zone with fitted modes (using Mix 3.1), and resulting frequencies (-).

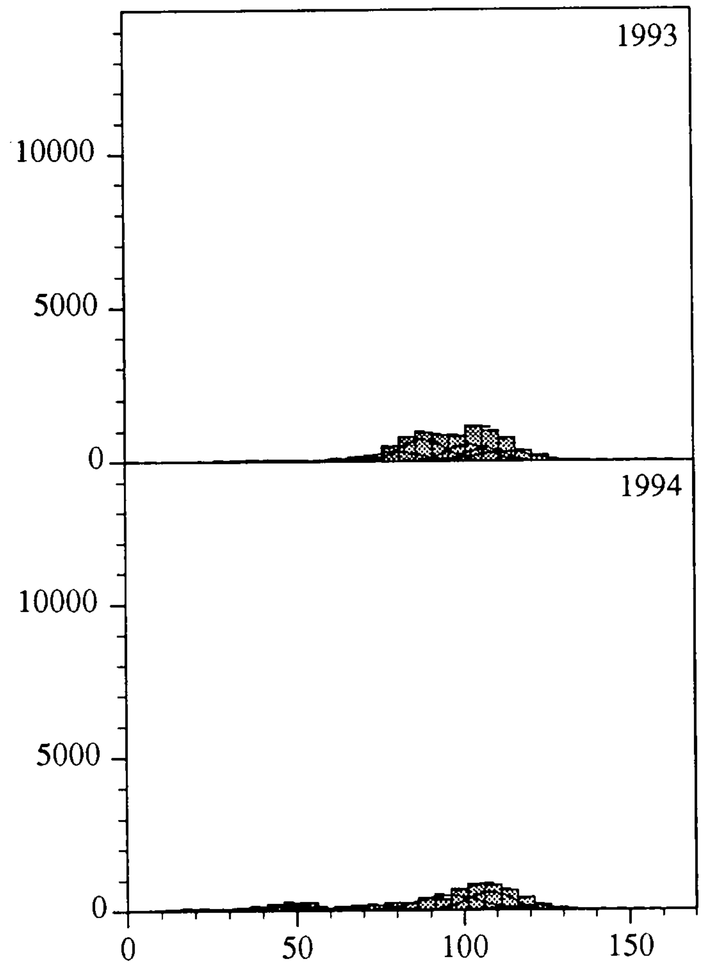


Figure 2B cont'd. Survey shell height frequencies for the outside zone with fitted modes (using Mix 3.1), and resulting frequencies (-).

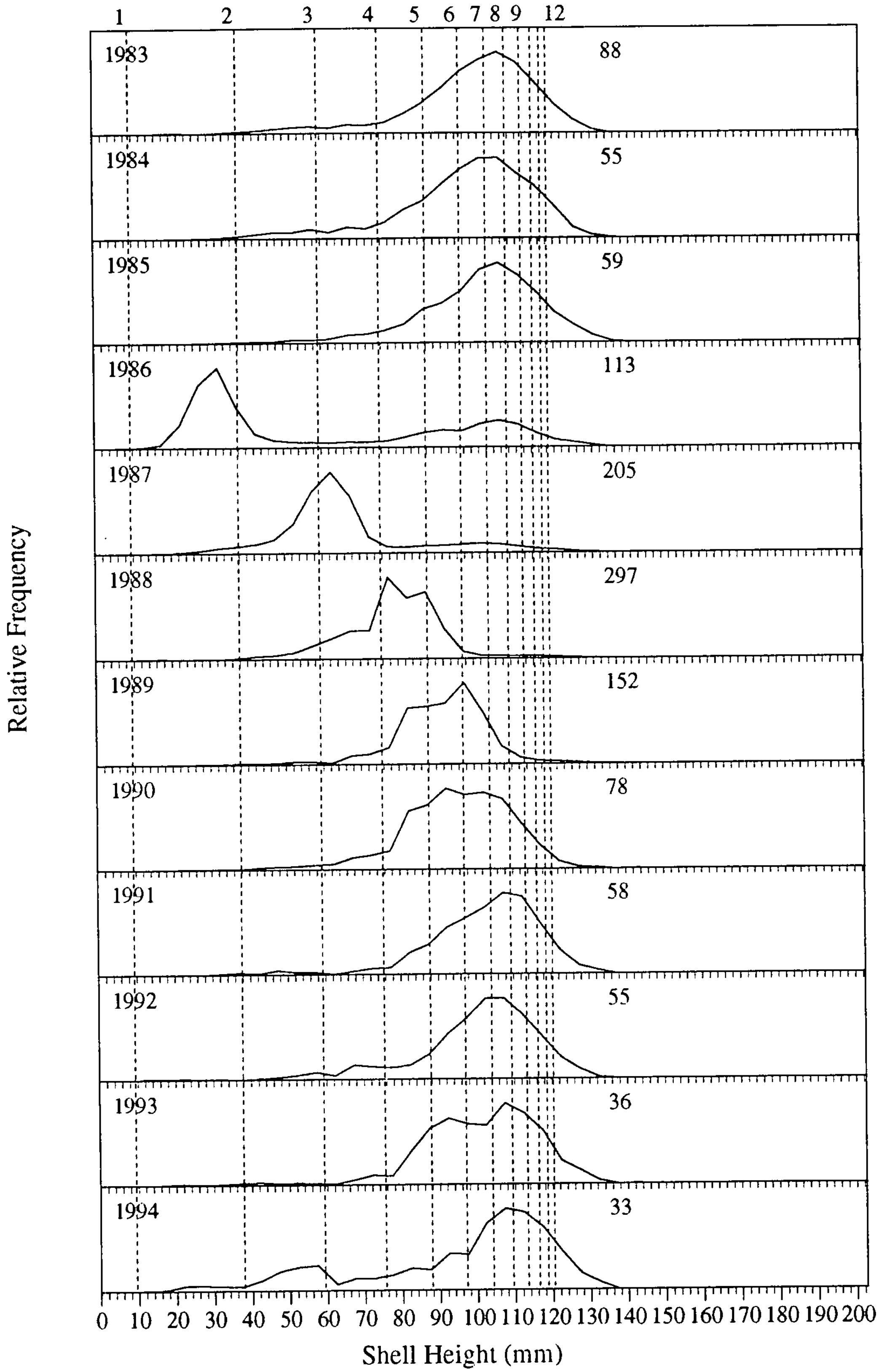


Figure 3. Shell height distribution pattern from research vessel survey catches from the outside zone, for 1983-1994. Total numbers of scallops ($x10^3$) is given in the upper right of each graph.

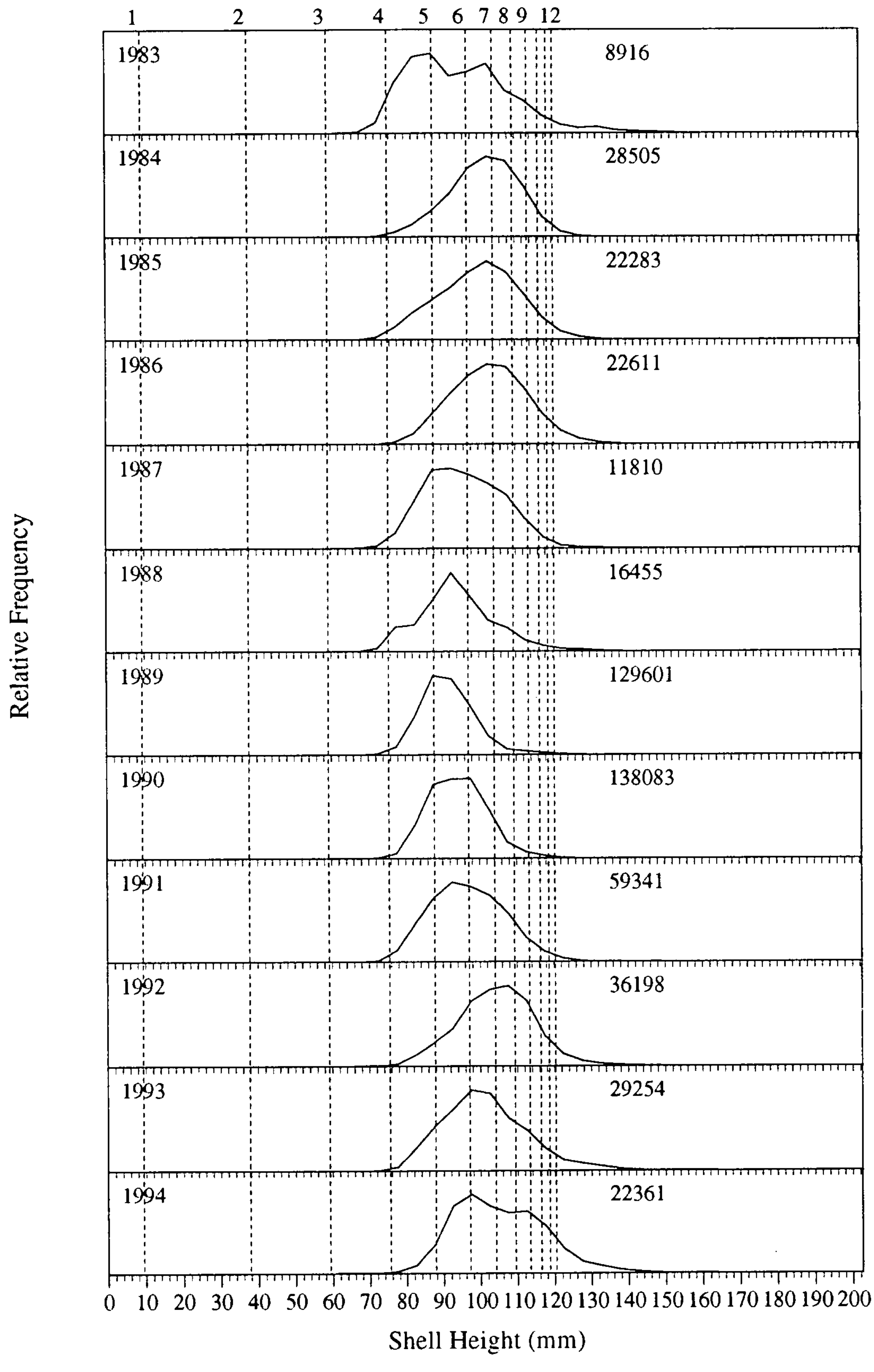


Figure 4. Shell height distribution pattern for the commercial catch from the outside zone, estimated from port sampling meat weight data for 1983-1994. Total numbers of scallops ($x10^3$) is given in the upper right of each graph.

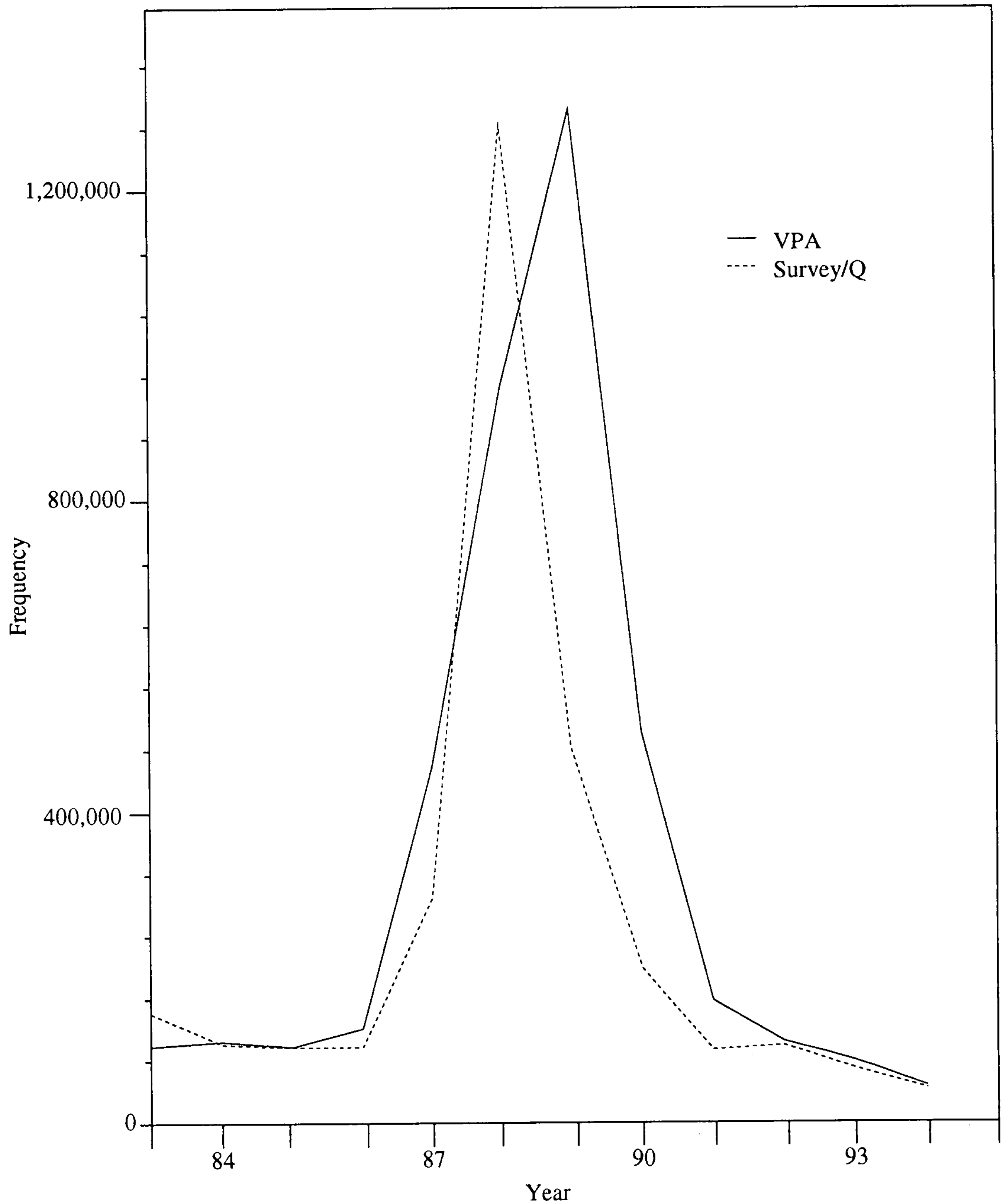


Figure 5. VPA and q-adjusted survey numbers for ages 4-7 for the outside zone, 1983-1994.

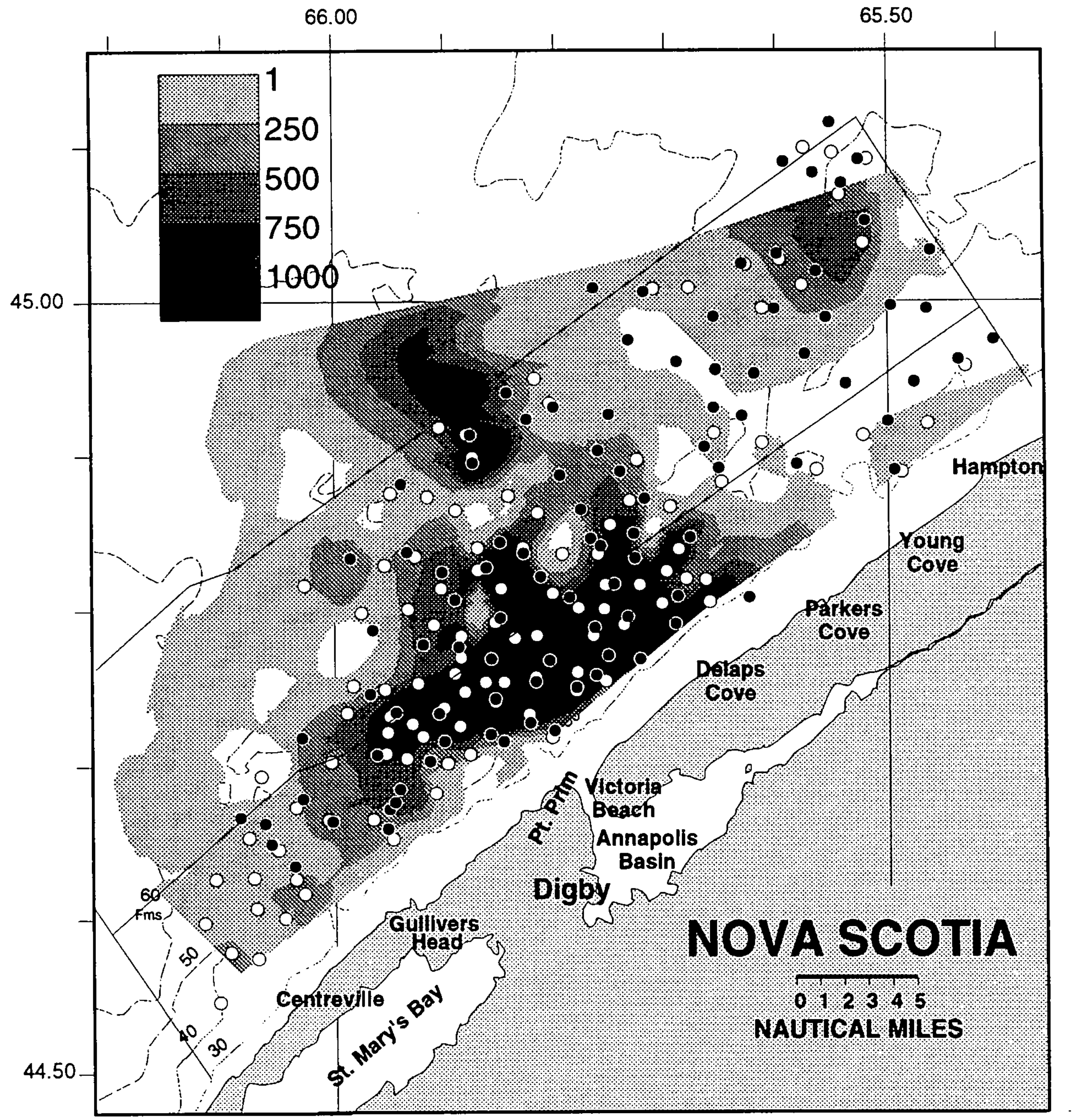


Fig. 6. Spatial distribution of age 2 scallops collected in the 1986 stock survey. Darkening shades of grey within isopleths refer to increasing number of age 2 scallops per standard tow. Locations of the 1988(●) and 1989(○) survey tow locations are indicated.

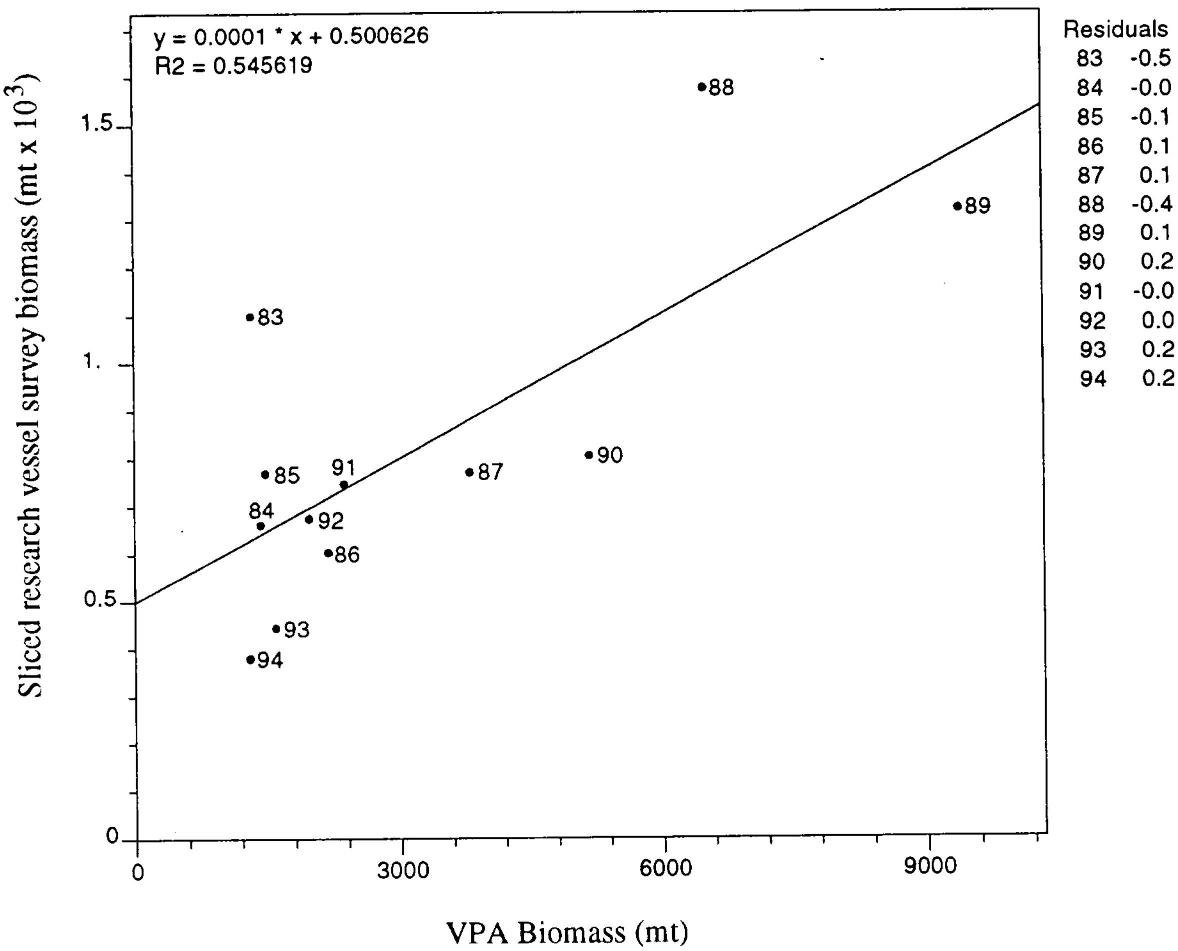


Figure 7. Regression of sliced research versus VPA Biomass estimates for ages 1^+, for the outside zone, 1983-1994. The residual for each yearly point is shown in the upper right margin of the graph. Regression equation and R^2 values are given.

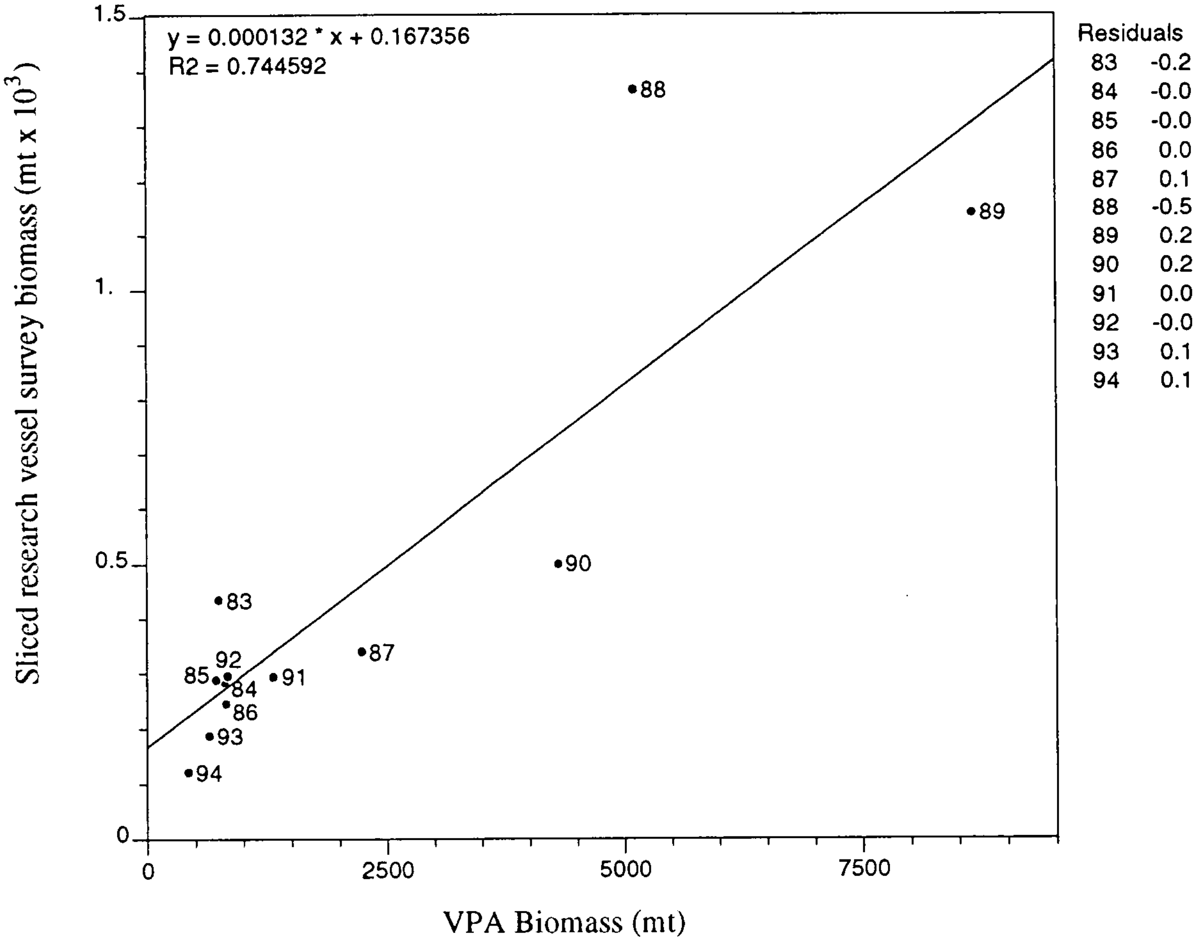
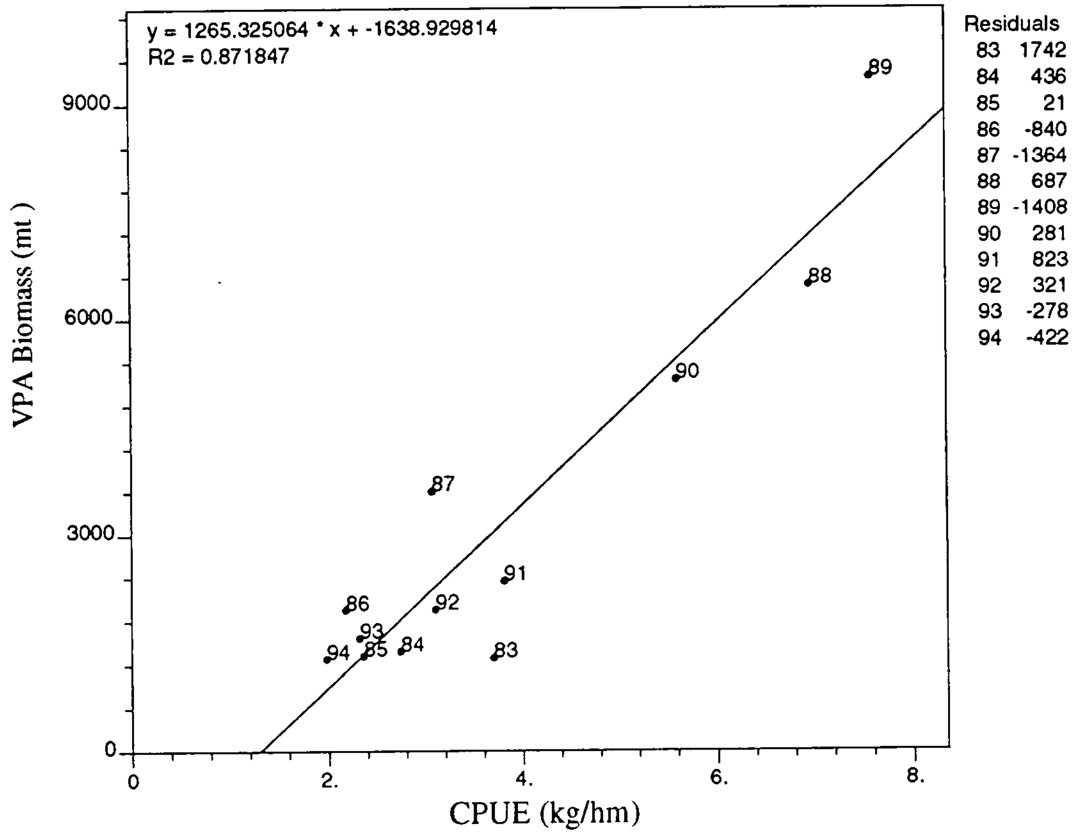


Figure 8. Regression of sliced research versus VPA Biomass estimates for ages 4-7, for the outside zone, 1983-1994. The residual for each yearly point is shown in the upper right margin of the graph. Regression equation and R^2 values are given.

(A)



(B)

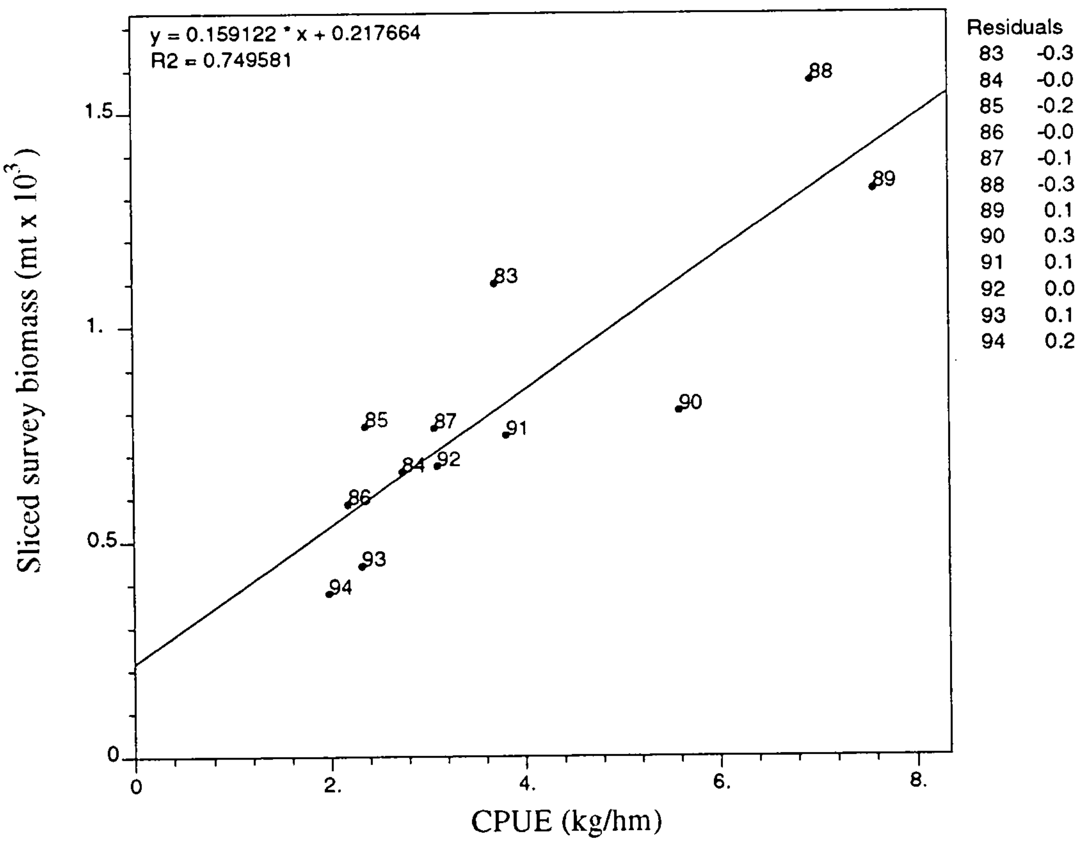


Figure 9. Regressions of age 3^+ biomass versus CPUE for (A) the VPA and (B) sliced survey results for the outside zone for 1983-1994. The residual for each yearly point is shown in the upper right margin of the graph. Regression equation and R^2 values are given.

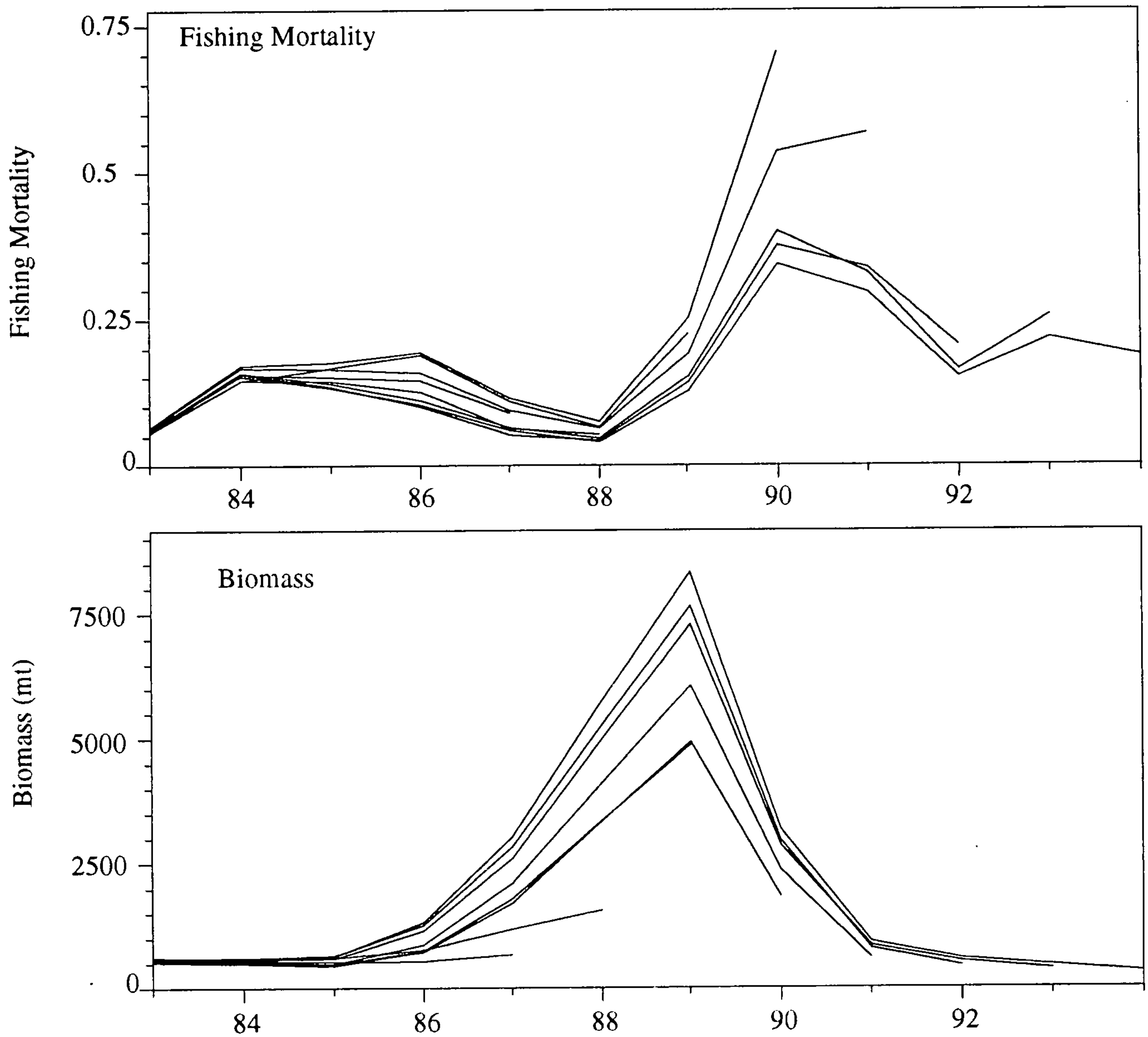


Figure 10. Retrospective analysis of fishing mortality (F) and biomass (mt) for ages 4-7 for the outside zone, sequentially peeling off the last 8 years data.

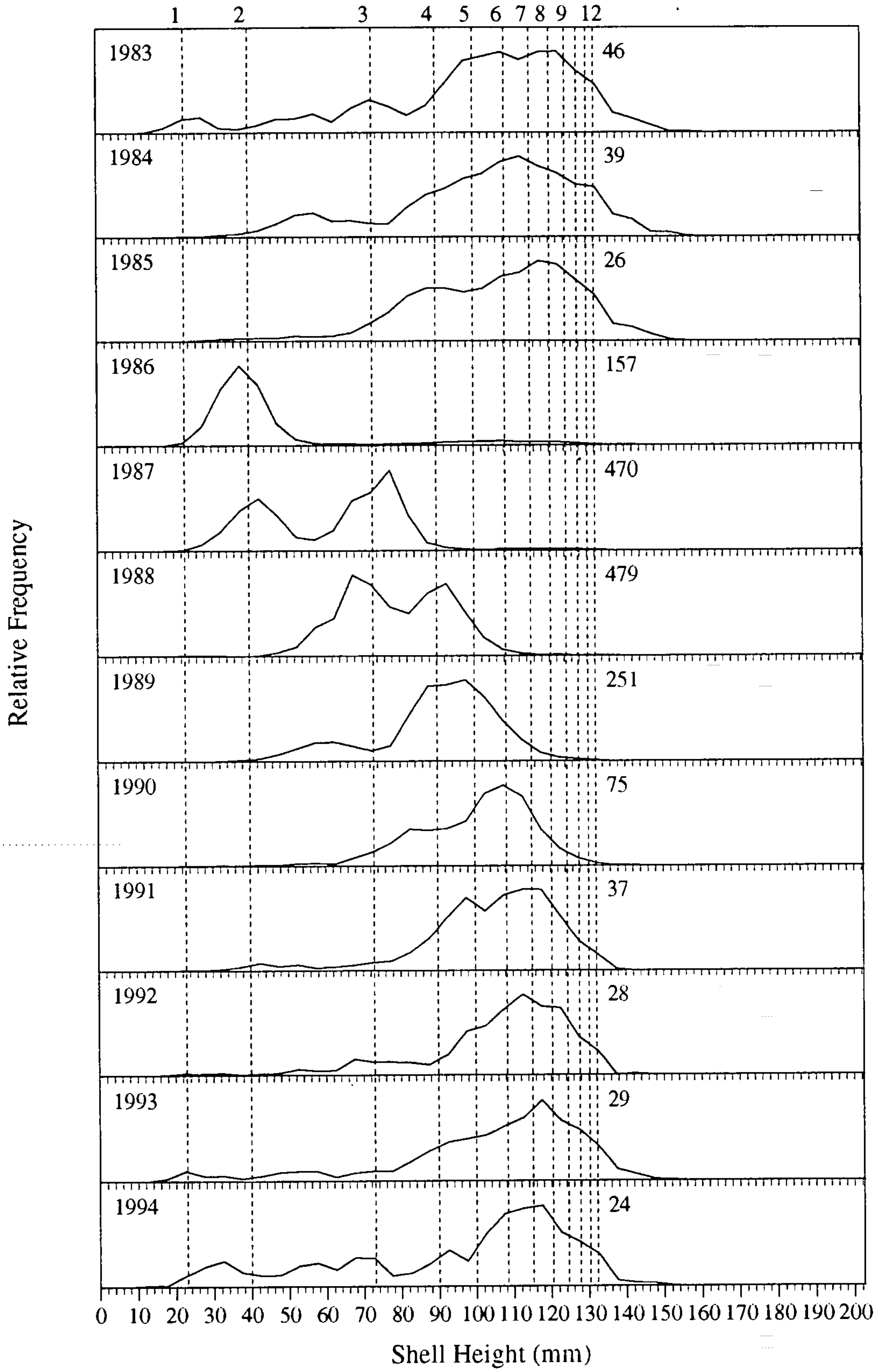


Figure 11. Shell height distribution pattern from research vessel survey catches from the inside zone, for 1983-1994. Total numbers of scallops ($x10^3$) is given in the upper right of each graph.

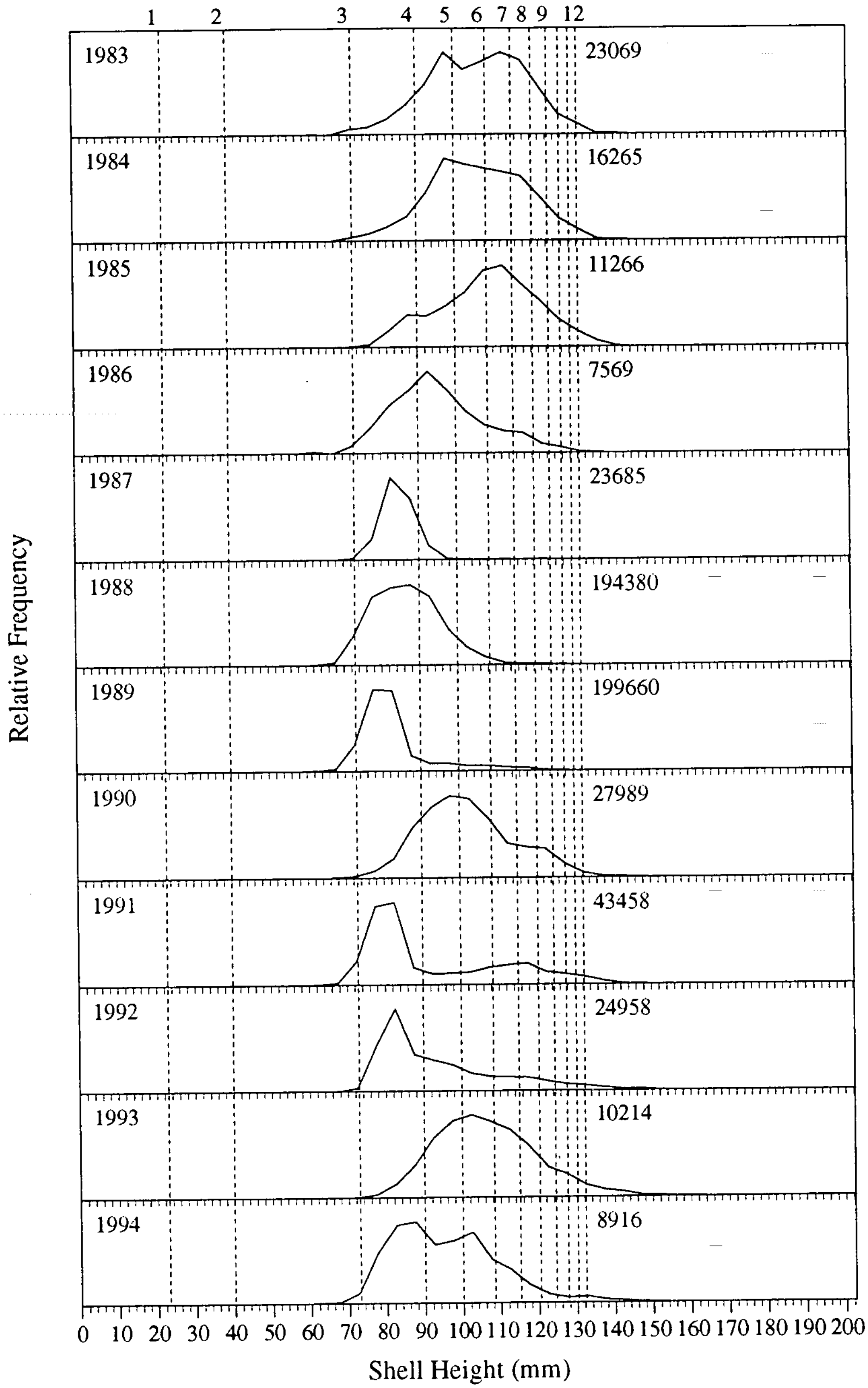


Figure 12. Shell height distribution pattern for the commercial catch from the inside zone, estimated from port sampling meat weight data for 1983-1994. Total numbers of scallops ($x10^3$) is given in the upper right of each graph.

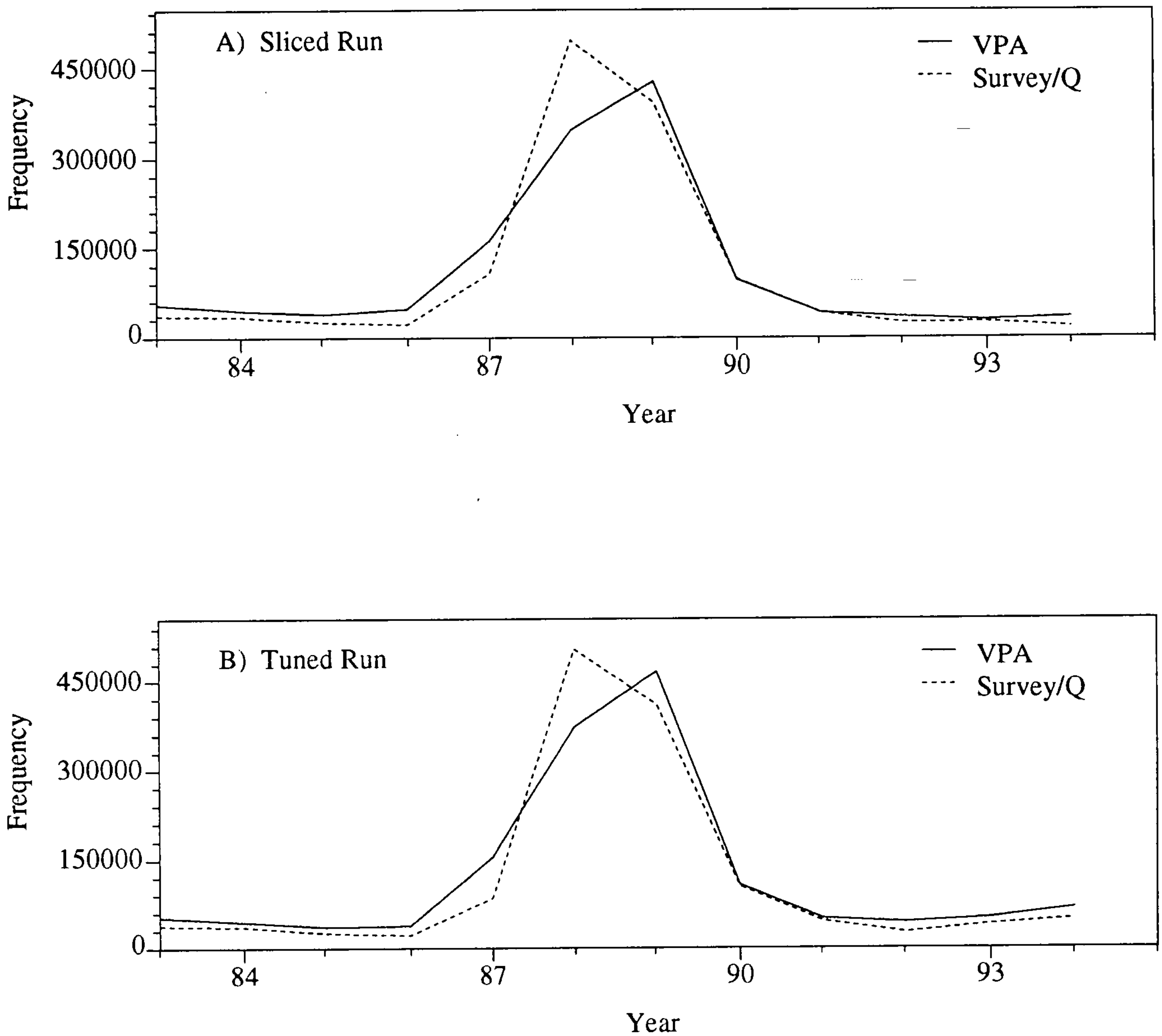


Figure 13. VPA and q-adjusted survey numbers ($x10^3$) for ages 4-7 for the inside zone, 1983-1994. (A) is the initial sliced run and (B) is after tuning.

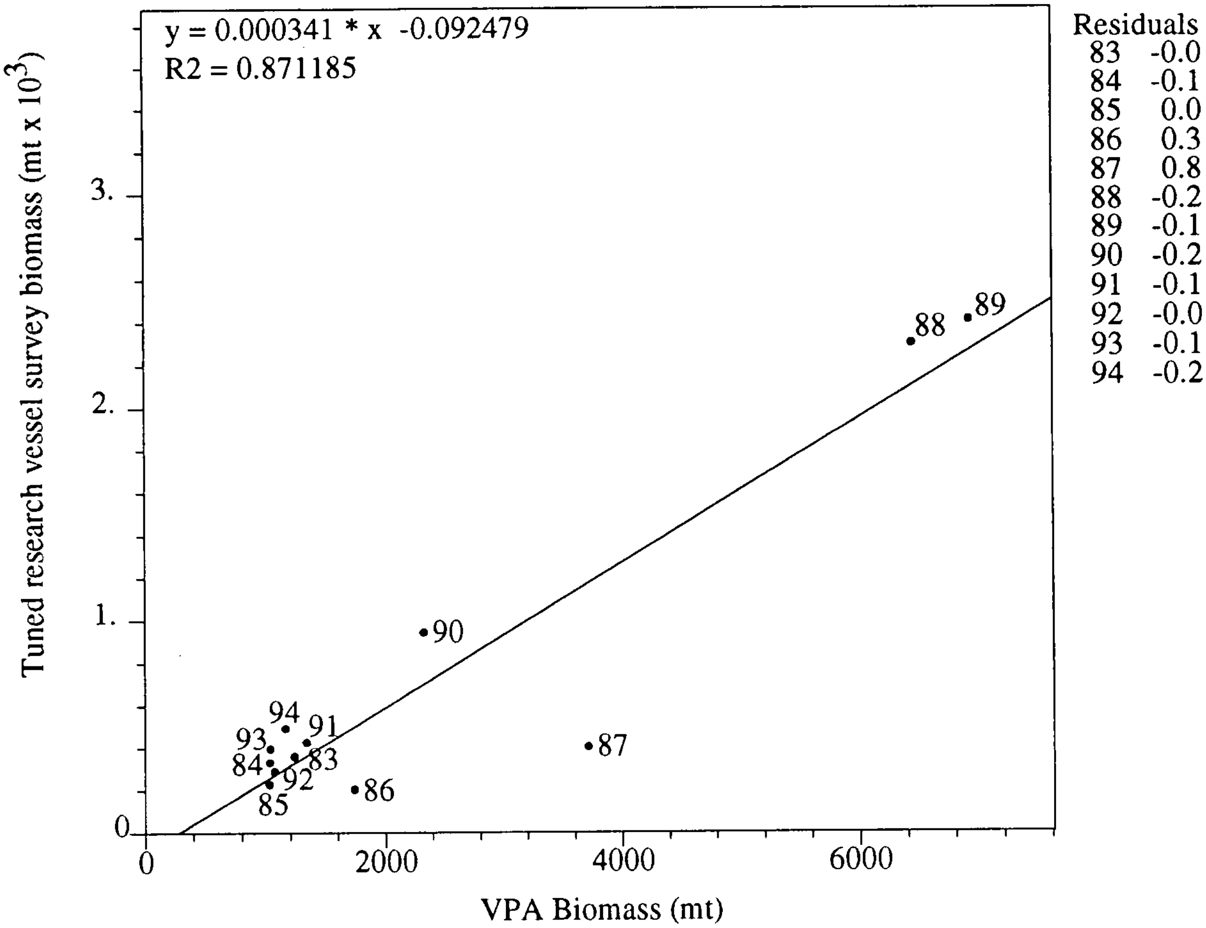


Figure 14. Regression of tuned research versus VPA Biomass estimates for ages 1^+, for the inside zone, 1983-1994. The residual for each yearly point is shown in the upper right margin of the graph. Regression equation and R^2 values are given.

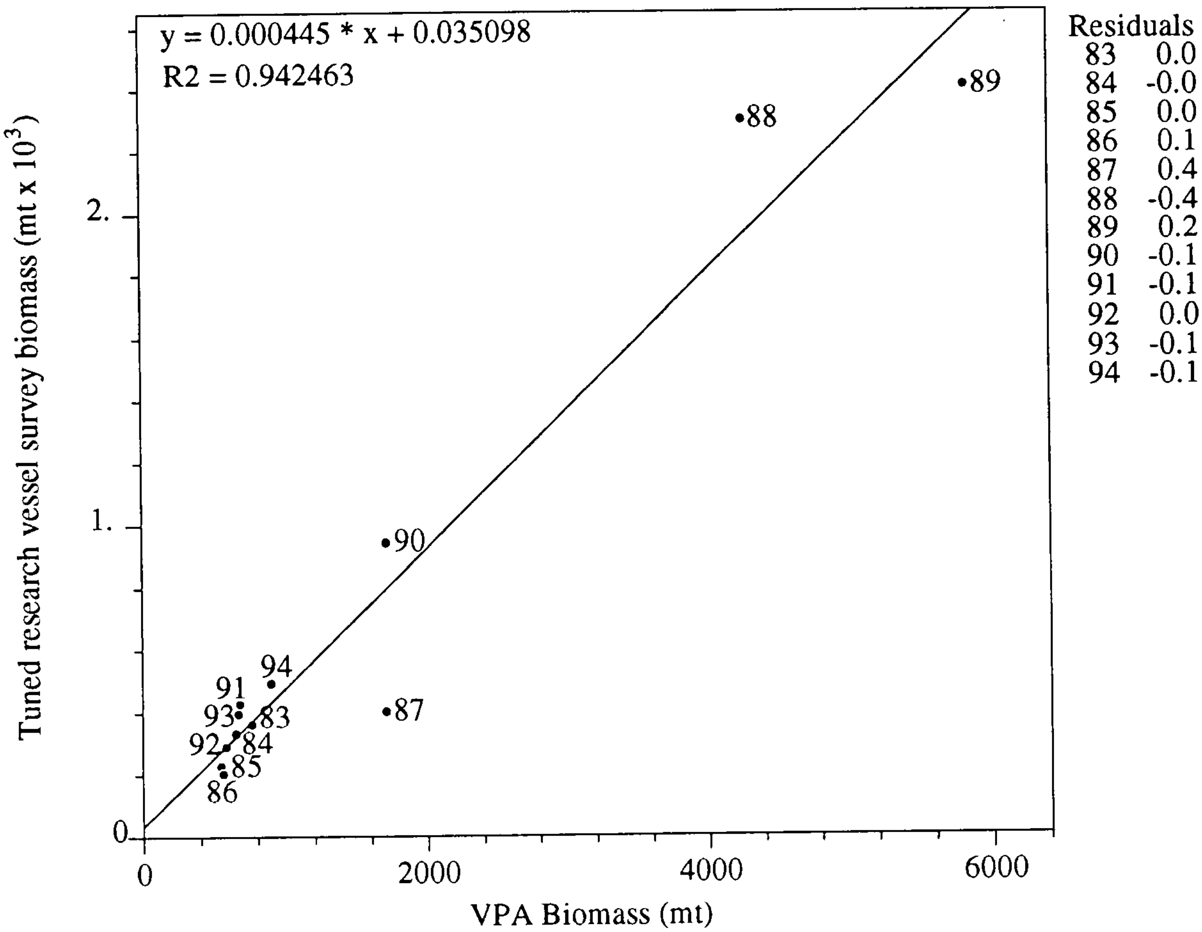
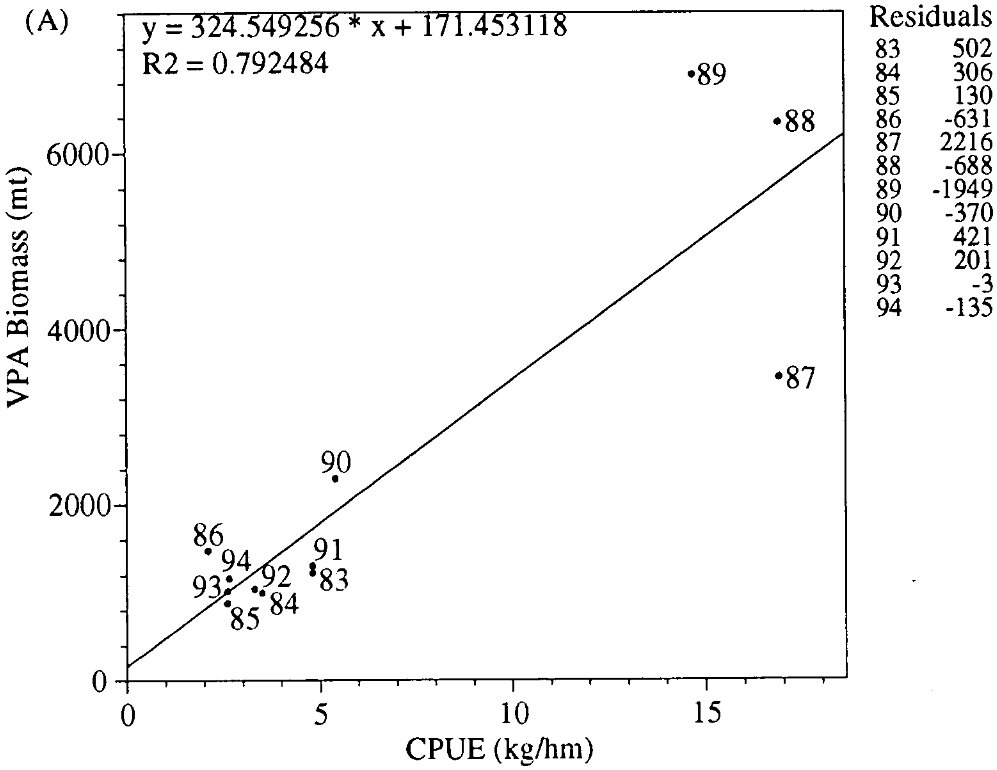


Figure 15. Regression of tuned research versus VPA Biomass estimates for ages 4-7, for the inside zone, 1983-1994. The residual for each yearly point is shown in the upper right margin of the graph. Regression equation and R^2 values are given.



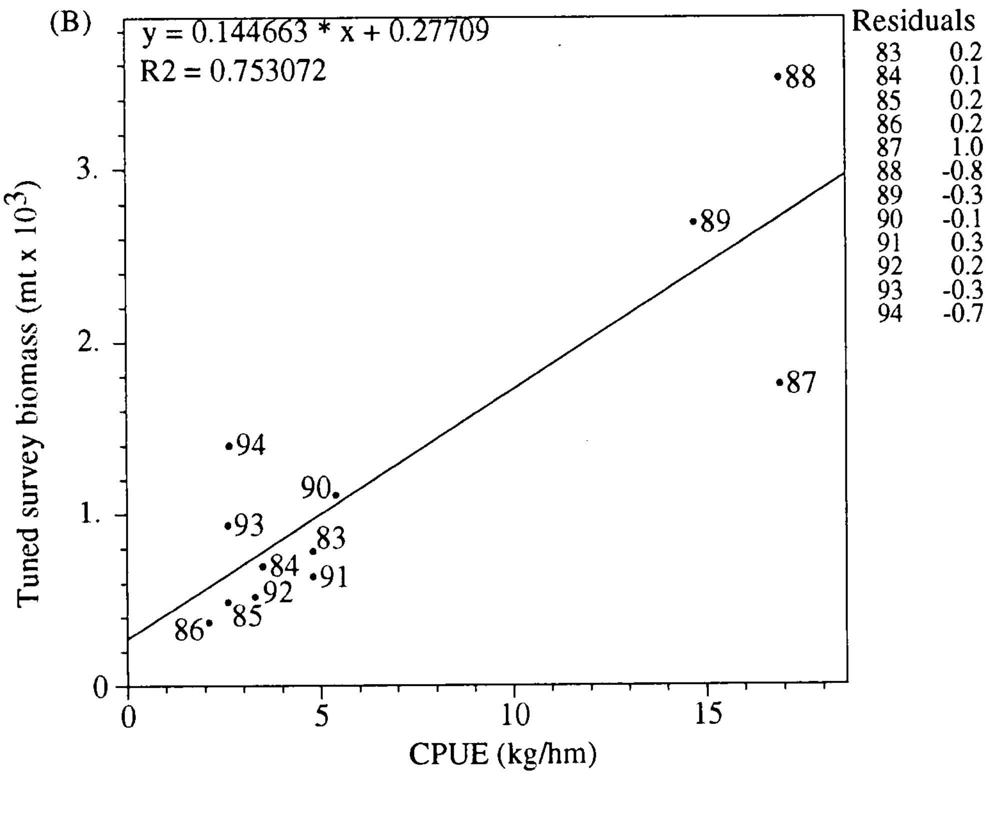


Figure 16. Regressions of CPUE versus age 3^+ biomass for (A) the VPA and (B) tuned survey results forthe inside zone for 1983-1994. The residual for each yearly point is shown in the upper right margin of the graph. Regression equation and R^2 values are given.

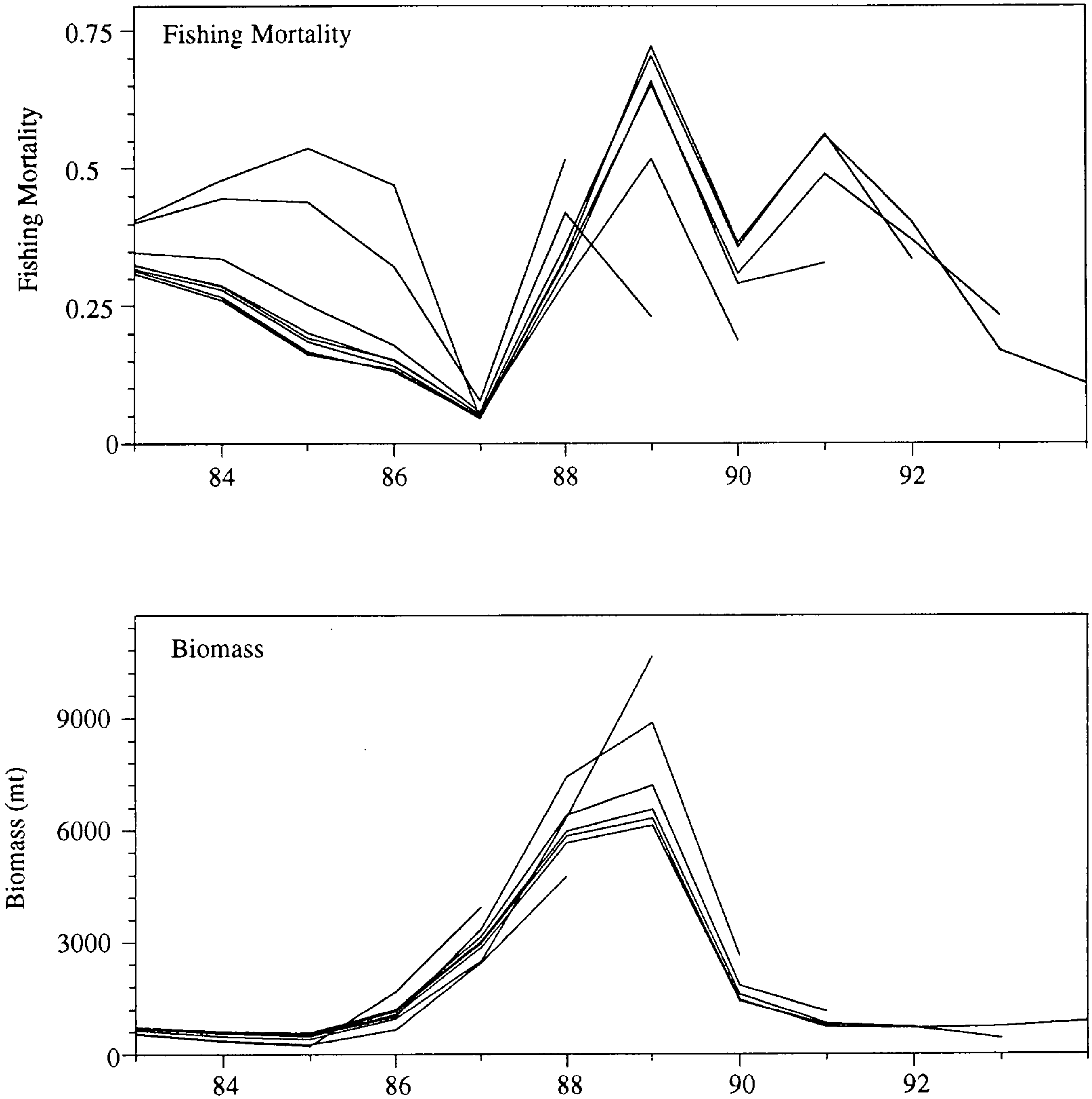


Figure 17. Retrospective analysis of fishing mortality (F) and biomass (mt) for ages 4-7 for the inside zone, sequentially peeling off the last eight years data.

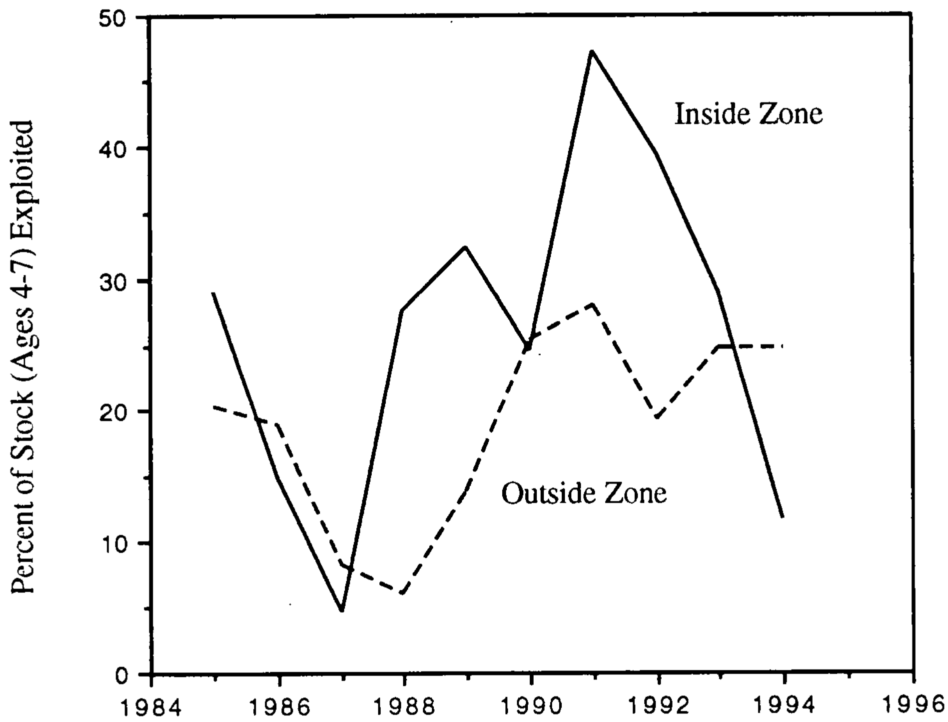


Figure 18. Percent exploitation of the 4 to 7 year-old scallops on the inside and outside zones off Digby.

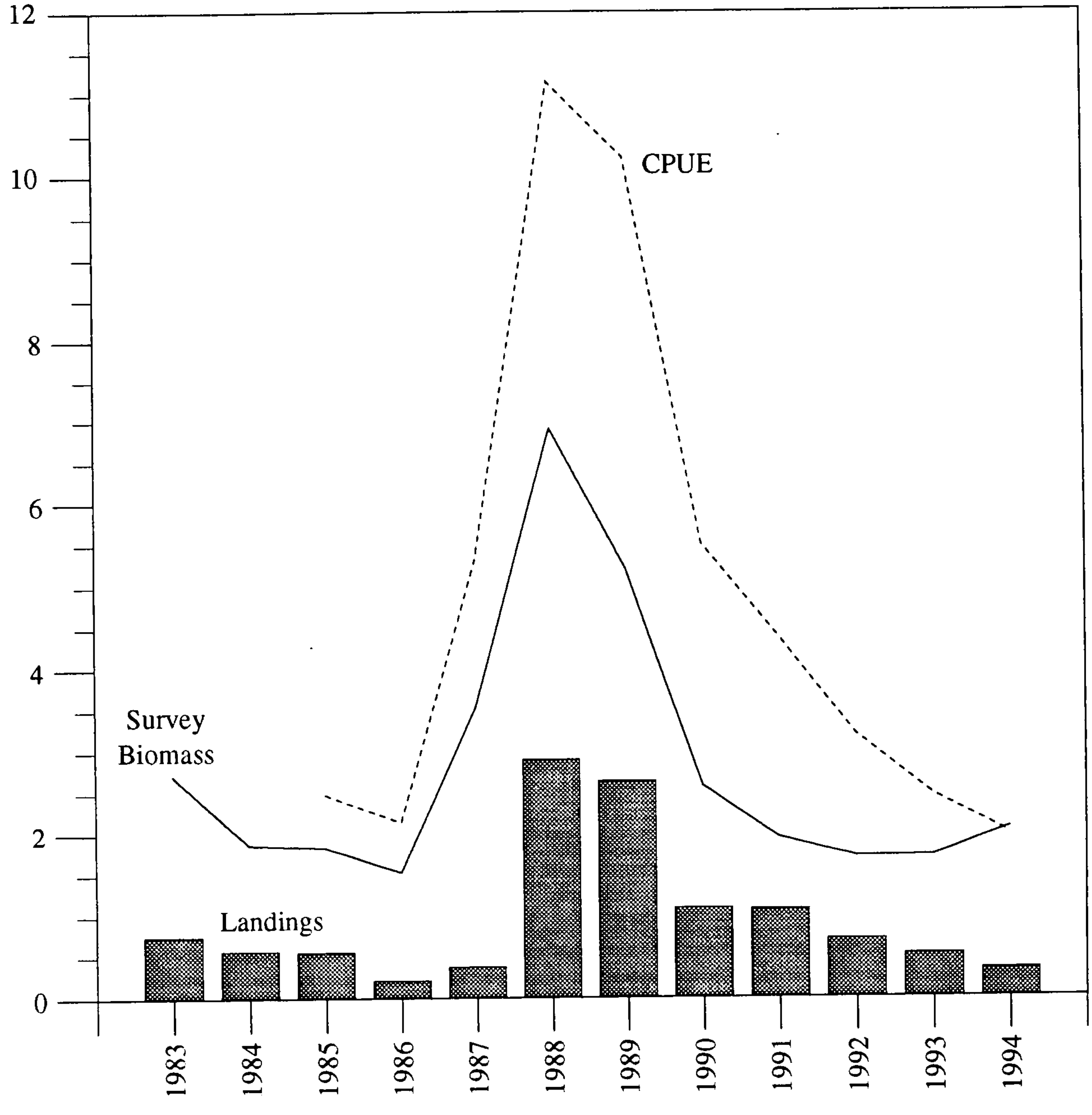


Figure 19. Landings (tonnes meats * 10^3), survey biomass (tonnes meats * 10^6), and CPUE (kg/hm) for the traditional Digby scallop beds.